PB-244 098

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS

Dick M. Whiting

National Climatic Center

Prepared for:

Robert S. Kerr Environmental Research Laboratory

June 1975

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

233111

EPA-660/2-75-018
JUNE 1975

PB244098

Environmental Protection Technology Series

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY STUDIES series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

EPA REVIEW NOTICE

This report has been reviewed by the Office of Research and Development, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

if

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-660/2-75-018	2.	3. PB 244 098
4. TITLE AND SUBTITLE USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dick M. Whiting		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Climatic Center (Asheville, NC) Environmental Data Service National Oceanic and Atmospheric Administration		10. PROGRAM ELEMENT NO. 1BB045 (ROAP 21-ASH, Task 18)
		11. CONTRACT/GRANT NO. EPA-IAG-D4-F451
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency, OR&D, NERC-Corvallis Robert S. Kerr Environmental Research Laboratory P. O. Box 1198 Ada, Oklahoma 74820		13. TYPE OF REPORT AND PERIOD COVERED Final (03/11/74 - 02/28/75)
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Planners, designers and operators of land-based wastewater management systems need information about climatic influences on the determination of storage requirements. Parameters of special interest are discussed and two guidelines have been developed. The guideline referred to as the freezing index is recommended for stations whose average normal temperature during the coldest month is less than 32°F, while a study of days defined as either favorable or unfavorable is recommended for stations in the warmer climatic zones. The effect of a run of unfavorable days immediately following a cold period can also be determined by examining the daily listings.

A number of graphs, charts and maps are included to describe ways of presenting climatological data and to show the availability of summarized climatic elements. Air temperature, ground frost, evaporation, precipitation, snowfall, snow depth and wind direction and speed are discussed in relation to the possible affect of each on land application systems.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Waste treatment Irrigation Design criteria Climatic changes	Soil treatment systems PRICES SUBJECT TO CHANGE	Pri. 04/02 Sec. 02/03

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 76
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE $4.75-2.25

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1975—698-780 /170 REGION 10

EPA-660/2-75-018
July 1975

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS

By

Dick M. Whiting
National Climatic Center
Environmental Data Service
National Oceanic and Atmospheric Administration
Asheville, North Carolina 28801

EPA-IAG-D4-F451
Program Element 1BB045
ROAP 21-ASH, Task 018

Project Officer

Richard E. Thomas
Robert S. Kerr Environmental Research Laboratory
National Environmental Research Center
P. O. Box 1198
Ada, Oklahoma 74820

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

ia

ABSTRACT

Planners, designers and operators of land-based wastewater management systems need information about climatic influences on storage requirements. Parameters of special interest are discussed and two guidelines have been developed. The guideline referred to as the Freezing Index is recommended for stations whose average normal temperature during the coldest month is less than 32°F, while a study of days defined as either Favorable or Unfavorable is recommended for stations in the warmer climatic zones. The effect of a run of unfavorable days immediately following a cold period can also be determined by examining the daily listings.

A number of graphs, charts and maps are included to describe ways of presenting climatological data and to show the availability of summarized climatic elements. Air temperature, ground frost, evaporation, precipitation, snowfall, snow depth and wind direction and speed are discussed in relation to the possible effect of each on land application systems.

This report is submitted in fulfillment of Interagency Agreement EPA-IAG-D4-F451 by the National Climatic Center (NCC), Asheville, North Carolina. Work was completed on February 28, 1975.

TABLE OF CONTENTS

		Page
ABSTRACT		ii
FIGURES		iv
CONVERSION TABLES		v
ACKNOWLEDGMENTS		vi
Sections		
I	CONCLUSIONS	1
II	RECOMMENDATIONS	2
III	INTRODUCTION	3
IV	NETWORKS OF OBSERVING STATIONS	8
V	SOIL TEMPERATURE	10
VI	GROUND FROST	12
VII	PRECIPITATION	15
VIII	EVAPORATION	16
IX	SNOWFALL	17
X	SNOW DEPTH	19
XI	WIND DIRECTION AND SPEED	21
XII	AIR TEMPERATURE	22
XIII	FREEZING DEGREE DAYS	23
XIV	FAVORABLE AND UNFAVORABLE DAYS FOR OPERATION	27
XV	REFERENCES	33
XVI	APPENDICES	37

FIGURES

No.		Page
1	Generalized Climatic Zones for Land Application	6
2	Relationship Between Freezing Index and Freezing Temperature Penetration for Various Surface Conditions for Granular and Fine-Grained Soils	11
3	Average Depth of Frost Penetration (inches) in the United States	13
3a	Extreme Frost Penetration (inches) in the United States	14
4	Extremes of Snowfall by States	18
5	Average Annual Number of Days with Snow-cover 1.00 Inch or More in Depth	20
6	Examples of the Freeze Index During a Mild Winter and a Cold Winter at Hampton, Iowa	24
7	Distribution of Mean Air Freezing Index Values in the Continental United States	25
8	Description of Chronological Listing Shown in Figure 9	29
9	Chronological Listing of Daily Weather Observations for Baltimore, Maryland for December 1960 with Computed Values	30
10	Seasonal Values of the Freezing Index, as Indicated, with Percentiles	31
11	Distribution of Sets of UNF-FA Days of Operation	32

CONVERSION TABLES

BRITISH TO METRIC UNITS

Length:

1 inch (in.) = 25.4 millimeter (mm.)
= 2.54 centimeter (cm.)

1 foot (ft.) = 30.48 millimeter (mm.)
= 0.3048 centimeter (cm.)

1 yard (yd.) = 91.44 centimeter (cm.)
= 0.9144 meter (m.)

1 statute mile (stat. mi.) = 1609.344 m.
= 1.609344 kilometer (km.)

Speed:

1 mile per hour (mi. hr.$^{-1}$, mph) = 0.868391 knot (kt.)
= 0.44704 m. sec.$^{-1}$
= 0.609344 km. hr.$^{-1}$

Density, Specific Volume:

1 pound per cubic foot (lb.ft.$^{-3}$) = 0.0160185 grams per cubic centimeter (g.cm^{-3})

Pressure:

1 standard atmosphere (14.7 lbs. in.$^{-2}$) = 760 millimeters of mercury (mm.Hg.)

1 millibar (mb.) = 0.750062 millimeters of mercury (mm.Hg.)

Temperature:

Celsius (C) = 5/9 (F-32) where F is temperature in degrees Fahrenheit

Absolute (A) or Kelvin (K) = C + 273.16

ACKNOWLEDGEMENTS

The leadership and assistance of Richard E. Thomas, Project Officer, Robert S. Kerr Environmental Research Laboratory and Frank T. Quinlan, Chief, Climatological Analysis Division, National Climatic Center, is gratefully acknowledged.

Previously published EPA reports containing results of investigations by Consultants Donald M. Parmalee, Dr. George Tchobanoglous, Dr. J. R. Mather, Charles E. Pound and Ronald W. Crites were referred to extensively in this report.

The cooperation of Wayne Tobiasson and Michael Bilello, U. S. Cold Regions Research and Engineering Laboratory and Mr. Douglas Griffes, Metcalf and Eddy, Inc. is acknowledged with thanks.

The author gratefully acknowledges the cooperation and support of the personnel in the several Divisions and Branches within the National Climatic Center who contributed to this report. Special thanks are extended to Mrs. June Radford and Mrs. Myra Ramsey for their contributions in typing and proof reading the report and to Miss Dorothy Goodman for preparing many of the graphs and charts.

SECTION I

CONCLUSIONS

The amount of wastewater storage required at a location because of climatic constraints can be estimated from analysis of weather station data with a program developed at the National Climatic Center. One feature of the program is an analysis of Favorable-Unfavorable days which shows the number of days during the winter season when operations will be restricted, based upon assigned thresholds for commonly measured weather parameters; a second feature is the Freezing Index which provides a measure of the intensity and duration of cold periods. When the index reaches 200 to 300 the ground is assumed to be frozen. The depth of frost penetration is not considered to be a critical factor in this program. Should it be necessary to estimate the depth of frost penetration, a graph is included for this purpose.

The lack of soil temperature data, the variability of winter temperatures from year to year and the differences in design and operating practices in the existing land application systems make it impracticable to accurately determine storage needs on the basis of available soil temperature data. An individual station analysis of climatic data can be extremely helpful in determining storage requirements once the limiting operating factors are defined.

SECTION II

RECOMMENDATIONS

Local decision making bodies should define acceptable climatic risks for the design of wastewater treatment plants. These criteria can then be used in the Freezing Index and Favorable-Unfavorable days program to determine the duration of non-operating conditions. It would be advantageous for climatologists to assist in the approximation of storage requirements.

It is recommended that the programs developed and discussed in this report be used as a test procedure to estimate storage needs with due consideration for the special operating practices designed for each installation. The climatological data should be applied only after decisions have been made as to the type of equipment, method of operation, expected volume, vegetation cover, loading rate, period of operation, etc.

SECTION III

INTRODUCTION

The application of wastewater effluents on the land is being practiced at several hundred sites throughout the United States.[31,35] These land utilization systems employ a multitude of land types and methods to dispose of different types of effluents with varying results. Representative information on the design, operation and performance of these systems can serve as a basis for defining good practice and determining the climatological constraints. Storage requirements must be accurately determined to avoid unplanned discharge of wastewater into streams and rivers due to under design or excessive costs due to over design. Climate constraints which prohibit irrigation are of special importance since they will help determine the long term storage needs.

The purpose of this report is to provide planners and designers of wastewater treatment systems with information about the type and availability of both raw and processed climatological data as well as possible methods of using these data as an aid for determining storage needs. This report describes two types of weather reporting stations, periods of record, elements reported, availability of digitized data (magnetic tape) and special programs developed by the National Climatic Center to provide summaries of selected climatological parameters for use in the decision making process.

In most land application operations, the vegetation cover is a major factor in the success of the system.[35] Both the rate of growth of vegetation and the rate of decomposition of organics in the effluent are regulated, in large part, by the energy available. Most places in the United States have sufficient energy for the development of a good ground cover of vegetation, although low levels of energy receipts in the winter in northern areas, with resulting low temperatures, will limit the rate of decomposition of any solids removed from the effluent.[30]

As stated in the CRREL Special Report No. 171,[34] "storage could be avoided if the land disposal site could function on a year-round basis; however, major risks to be considered prior to adopting year-round application include wintertime constraints on the movement of water, and wintertime response of the site ecosystem." The special report goes on to point out that winter time application can reduce the renovative capability of the site and inhibit the chemical reactions in the soil. For example, some systems obtain nitrate removal by plants and micro-organisms in the ecosystem and since these are essentially dormant in winter, nitrate losses could be significant.

If land application in northern latitudes is planned only during the warmer months, the application period might vary from 20 to 40 weeks (March-November) depending on local conditions.[34] Storage and/or some other form of treatment will be necessary for the remainder of the year. Further restrictions might also be necessary during the warm months since spray irrigation should be avoided during periods of high winds and it may be desirable to cease all wastewater application during periods of intensive rainfall.

The three principal methods used in land application of wastewater are irrigation, overland flow and infiltration-percolation. According to an Environmental Protection Agency (EPA) publication[35] irrigation is the most reliable land application technique with respect to long term use and removal of pollutants from the wastewater, while overland flow and infiltration-percolation methods are feasible in many cases. The storage requirements estimated from climatic constraints may have to be supplemented depending on the date irrigation is required in the spring. Climate will affect irrigation and overland flow more than infiltration-percolation because the water needs of plants are affected by air temperature, humidity, solar radiation, and wind velocity.

Other disposal methods include subsurface leach fields, injection wells and evaporation ponds. EPA publications[31,35] refer to the importance of making a proper assessment of the type of system suitable for a given situation. The principal factors are classified as regulatory, economic and technical. The technical factors include the physical aspects of the land, underground formations, ground slope, wastewater characteristics and flow rates, climate and whether the flow remains constant throughout the year.

The extent to which weather affects the operation of a system depends on the type of system and equipment, as well as the volume of effluent. Some small systems are known to operate continuously during severe winters, while others utilize storage ponds capable of holding four to six months of effluent.[31] Obviously, climatic constraints to operation are quite variable and depend on the particular system and location. This demonstrates the fact that no hard and fast guidelines on climatic constraints can be established under all conditions.[31,35]

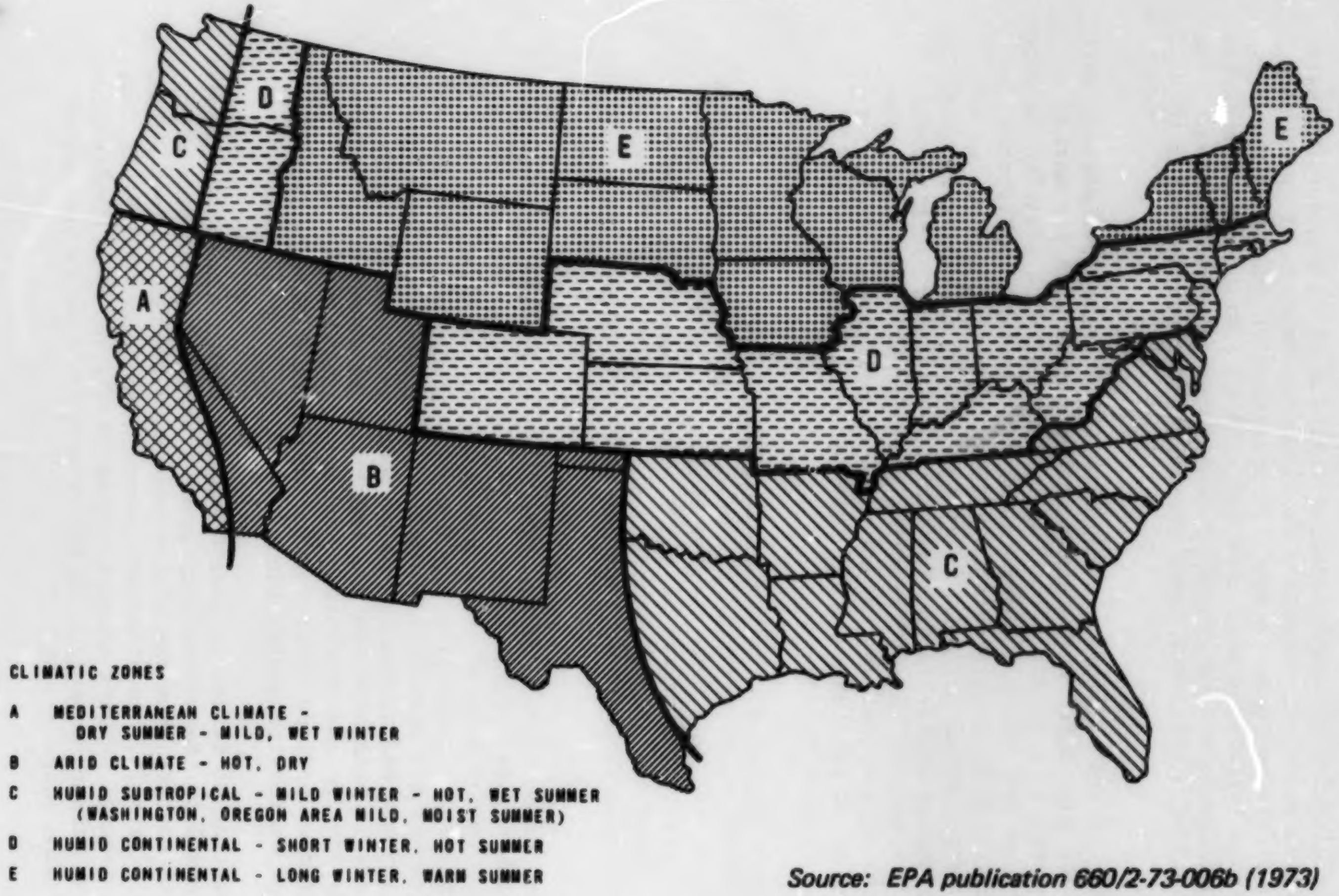
The following material concerning generalized climatic zones for the United States (Figure 1) was prepared for the Environmental Protection Technology Series 660/2-73-006 and published in August 1973.[35] The map is a useful guide although detailed analysis of climatological data at the location under consideration is also recommended. In preparing the map, an effort was made to simplify distribution patterns; where possible, state boundaries were used for ease in setting zone boundaries even though climates seldom change at such political sub-divisions. The classification of mountainous areas should be adjusted according to elevation.

Zone A, which covers California except for the extreme southeastern part, delineates the unique Mediterranean climatic region with its marked seasonal pattern in precipitation. Average annual precipitation is about 15 to 25 inches confined generally to the six months from November to April; practically no precipitation falls in the other six months of the year. Temperatures are mild in winter and hot in summer so that adequate energy is available in almost all seasons for plant growth. Storage of the effluent due to freezing will not be necessary except at higher elevations, but may be desirable to maximize summer application rates or to make the addition of nutrients in wastewater correspond to crop requirements.

Zone B covers southwestern United States, an area of very hot, arid climates. Winter storage should not be a concern in most of the area although there will be a real problem due to the lack of sufficient moisture for vegetation growth in all seasons unless irrigation is available. There may also be problems of salt in the soil if brackish water is used in irrigation or constitutes a significant portion of the effluent.

Zone C covers primarily the states identified as the Mid and Deep South as well as the western portions of Washington and Oregon. In general, precipitation varies from 40 to 60 inches during the year, and average monthly temperatures range from the low 40's in winter to the low 80's in summer, except for part of the Washington-Oregon area which experiences mild summers and winters. Twelve-month operation of land application systems is possible from the standpoint of temperature. However, the well distributed and relatively high precipitation eliminates the need for extended periods of irrigation which are desirable from the standpoint of wastewater application.

The northern tier of states in Zone C and the states along the southern border of Zone D in the midwest represent areas that experience wide variations in weather from one winter season to the next. Fort Smith, Arkansas, for example, has a January normal temperature of 39.0°F, but recorded an average January temperature of 26.4°F in 1940. Dodge City, Kansas with a January normal of 30.8°F recorded a January average of 16.6°F that same year.


A
B
C
D
E
CLIMATIC ZONES
A MEDITERRANEAN CLIMATE - DRY SUMMER - MILD, WET WINTER
B ARID CLIMATE - HOT, DRY
C HUMID SUBTROPICAL - MILD WINTER - HOT, WET SUMMER (WASHINGTON, OREGON AREA MILD, MOIST SUMMER)
D HUMID CONTINENTAL - SHORT WINTER, HOT SUMMER
E HUMID CONTINENTAL - LONG WINTER, WARM SUMMER

Source: EPA publication 660/2-73-006b (1973)

Fig. 1 Generalized climatic zones for land application

Zone D covers the middle tier of states running eastward from Colorado to southern New England and the eastern portions of Washington and Oregon. The climates are marked by moderately cold winters (average temperatures in the 20's), hot summers (average temperatures in the mid-70's), and precipitation well distributed through the year. Some irrigation might be needed in the western portion for vegetation development, but little would be needed in the east. Winter temperatures are cold enough so that effluent storage for several months or so may be necessary.

Zone E covers the northernmost tier of states. Very cold winters with warm summers and adequate moisture for vegetation exist. Winter operation of irrigation systems is quite limited because the low temperatures, with ice and snow, contribute to the storage of effluent for up to six months.

Evaluation of the effect of large land application systems on local climatic conditions is difficult because of the lack of observations. However, it is possible to draw certain conclusions on the basis of observations taken around reservoirs both before and after their establishment, from studies in the vicinity of large irrigation enterprises, and on the basis of various theoretical considerations.

According to Dr. J. R. Mather,[31] "the climatic changes that accompany irrigation enterprises are relatively local in extent. Air moving over an irrigated tract will rapidly pick up moisture and the air temperature will cool. Within the first few hundred feet in all but the most arid region, the air will have essentially reached equilibrium. Once the air has left the moist area, turbulent mixing will, within just a few miles, reduce its moisture content to its original low value and return the temperature to its value upwind of the irrigated tract."

It has been recommended that wastewaters with high temperatures be cooled prior to land application because of the adverse effect on both vegetation and soils.[31] Cooling ponds or lagoons used for this purpose might be a source of fog during the period from November through April in many parts of the country, especially in climatic Zones D and E.

SECTION IV

NETWORKS OF OBSERVING STATIONS

The National Weather Service and its Cooperative Networks collect a great deal of climatological data at thousands of locations. (See Appendix B.) The National Climatic Center publishes much of this information on a State basis by month, and annually. (See Appendix C.) Many of the original observations are digitized and retained on magnetic tape for rapid computer processing as the need arises. Single station summaries based on long periods provide a variety of detailed information about the climate of an area. The large number of programs developed at the National Climatic Center over the years provides a broad base of useful climatological information to all segments of the economy.

When the climatological material required can be clearly specified, it may be ordered and sent on an invoice. If, however, the needs are not clearly known, or cannot be adequately described in terms of available National Climatic Center programs, the services of a consultant to assist in developing the specifications and interpreting the results are recommended.

The analysis of climatological data can provide insight into the special problems of planning, design and location of land application systems. It can also be useful in studies relating to the growth and yield of plants. It is very important to establish which climatic parameters are essential to a specific problem, to process the data to obtain meaningful results and, most importantly, to correctly evaluate the results of such programs in terms of both cost and risk.

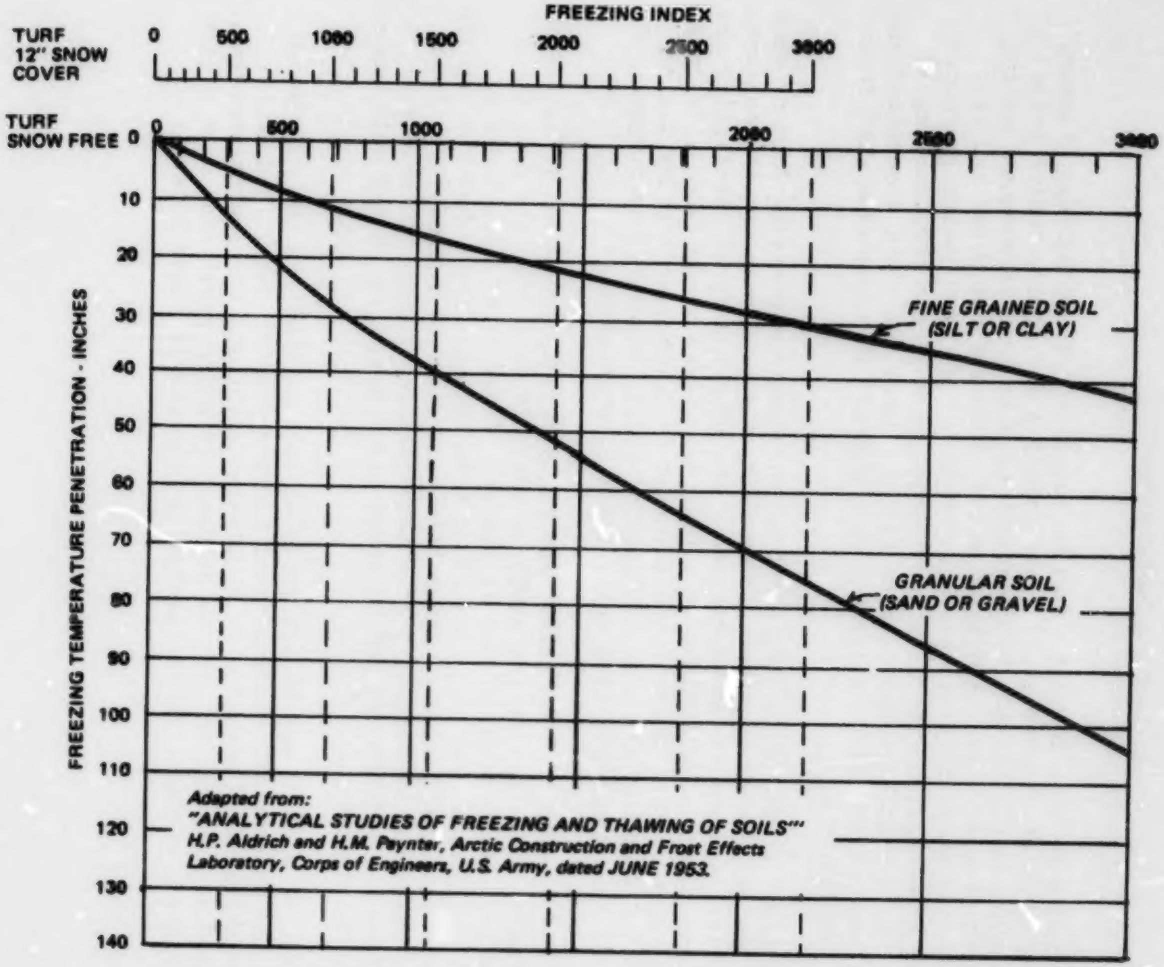
All climatological studies are limited by the type, amount and condition of the available observational data. The daily temperature, precipitation and snowfall data used in the program referred to in this report represent the best long term daily data available on a nationwide basis. Unfortunately, these observations contain only a few of the desired elements. Because climate cannot be described simply, or reduced to a single figure, decisions will most likely be based on probabilities after the planner has examined all available information.

The National Climatic Center's data base includes over 40,000 reels of magnetic tape. Observations are received from over 10,000 stations in the United States; however, there are differences in the type of elements reported and hours of observation. Some stations report on an hourly or three-hourly basis, while the majority of the stations report only the daily maximum and minimum temperatures and total precipitation. In any case, a survey can be made to select the weather station which has the appropriate data in digital form and is most representative of the selected site. Some of the elements, tabulations and programs described in the Appendices are discussed briefly in the following paragraphs.

SECTION V

SOIL TEMPERATURE

The EPA summary[35] recommends that climatic investigation be undertaken to define simultaneously surface soil and ambient air temperature for the United States. Such information would be useful in determining the annual period in which vegetation and active bacterial metabolism might be maintained by wastewater application. However, relatively few stations report soil temperatures on a regular basis. Unfortunately, neither the hours of observations, nor the depths at which the sensors are placed have been standardized. Because of this and the differences in soil types, ground cover, slope, etc., no attempt has been made to define simultaneous surface soil and ambient air temperature relationships. Figure 2 shows the relationship between the Freezing Index and freezing temperature penetration for various surface conditions for granular and fine grained soils. Other maps of interest are shown in the Appendices.



Adapted from:
"ANALYTICAL STUDIES OF FREEZING AND THAWING OF SOILS"'
H.P. Aldrich and H.M. Paynter, Arctic Construction and Frost Effects
Laboratory, Corps of Engineers, U.S. Army, dated JUNE 1953.

Fig. 2 Relationship between freezing index and freezing temperature penetration for various surface conditions for granular and fine-grained soils

SECTION VI

GROUND FROST

No article on this subject would be complete without making reference to the work of Jessberger.[19] This detailed and comprehensive volume of some 500 pages carries a bibliography of over 1300 references dealing with the freezing and thawing of soils, structure of water and ice, mechanical properties of ice, etc. Much of the text covers the underlying principles of the effects of frost on soil and the carrying capacity of roads in relation to frost. Other important investigations have been carried out by Aldrich and Paynter[1] in connection with frost penetration.

Jessberger states that "the frost depth beneath a covering free of snow and ice depends on the Frost Index (FI), the properties of the subjacent materials and the water conditions. The expected frost penetration can be approximately determined as a function of the accumulated cold in a freezing period." Much of the interest in Jessberger's study was in road building and the load capacity of roads; however, the fundamentals are of importance for land application of wastewater.

For the purpose of this report and the programs discussed, it is not necessary to determine the depth of the 32°F isotherm, but only to establish whether the ground is frozen. There is no question that such information may be critical at some installations when the applied effluent is considerably warmer than the ground. Investigation into such cases may be necessary at sites operating twelve months a year, but will necessarily be limited to those locations which record soil temperature measurements.

(NOTE: Figures 3 and 3a are included because they are the only known maps of average and extreme frost penetration for the United States. No background information is available concerning the source material, method of computation, or the document in which these maps were originally published. Caution is recommended in the use of these maps.)

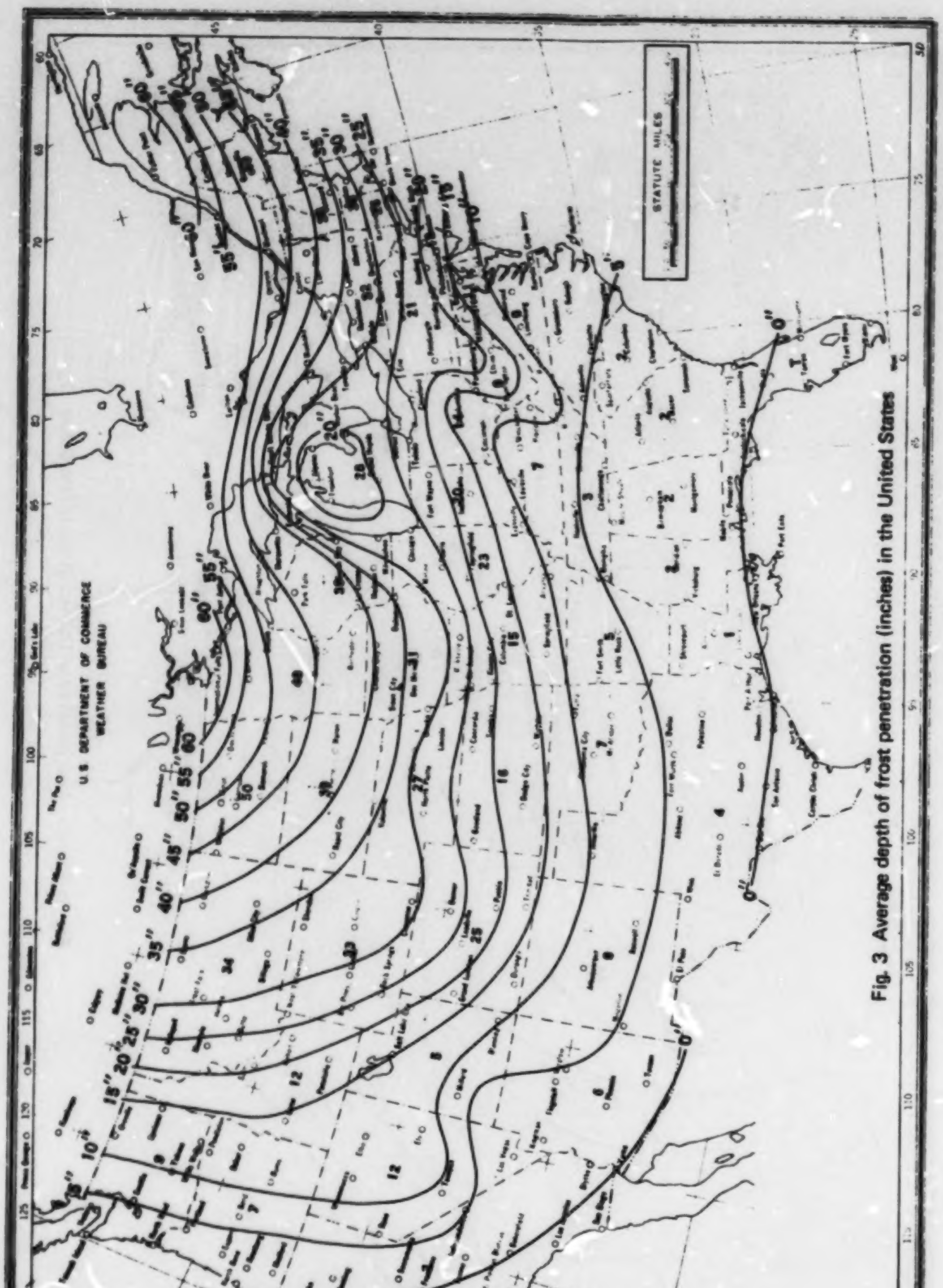

U S DEPARTMENT OF COMMERCE
WEATHER BUREAU
STATUTE MILES
0"
5"
10"
15"
20"
25"
30"
35"
40"
45"
50"
55"
60"

Fig. 3 Average depth of frost penetration (inches) in the United States

Reproduced from best available copy.

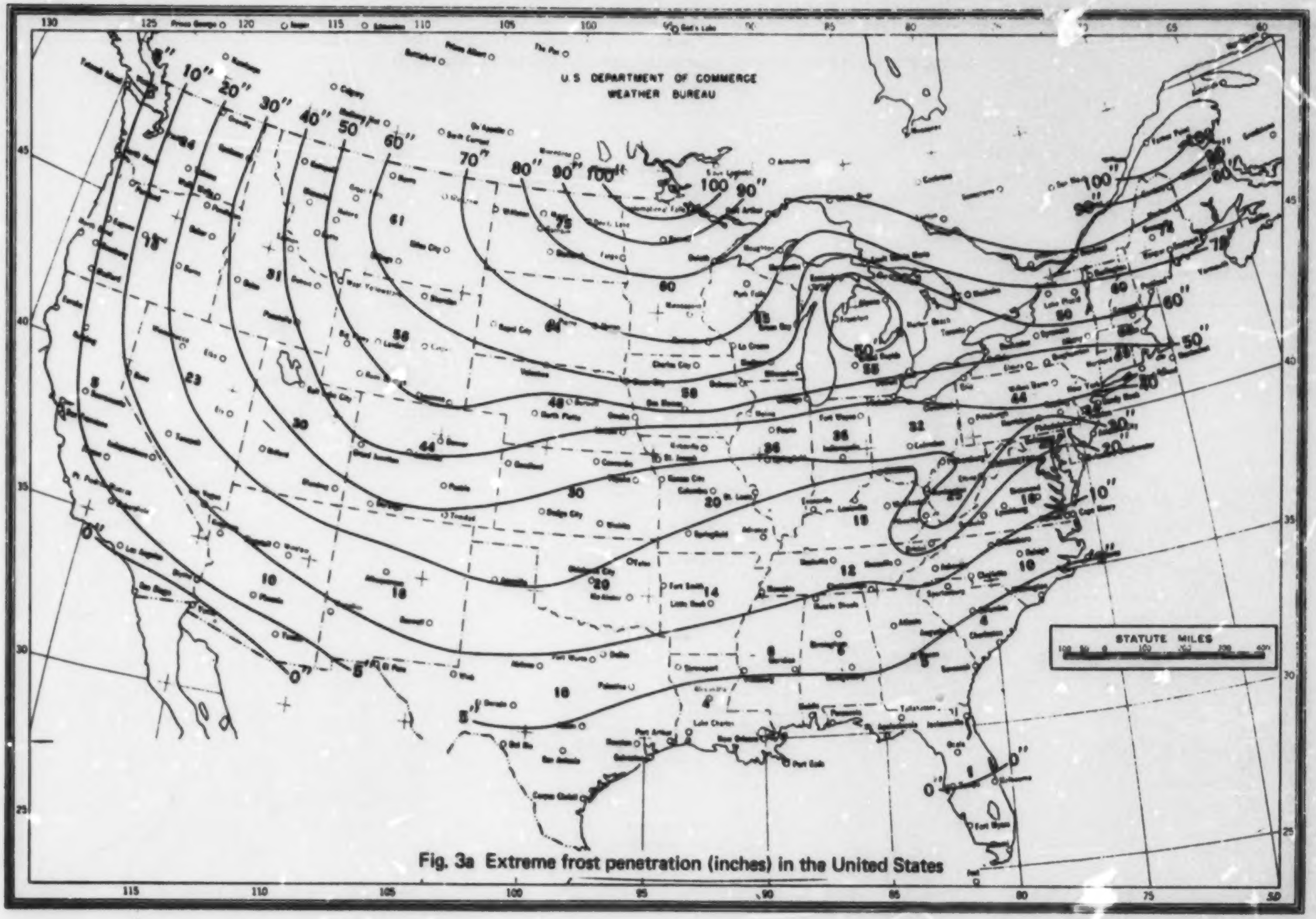

U.S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
STATUTE MILES
0"
5"
10"
20"
30"
40"
50
60"
70"
80"
90"
100"

Fig. 3a Extreme frost penetration (inches) in the United States

SECTION VII

PRECIPITATION

The water balance is governed primarily by precipitation, evaporation and transpiration of the plant. The requirements of water are very different from one plant species to another as well as at different time periods throughout the year. There are times when too much water is as detrimental as is insufficient moisture at other times.[13]

Precipitation probabilities, frequency distributions and maps have been prepared which furnish useful information on a local, state and national level.[25,37] Many of the estimated probabilities are for one, two and three week periods, while others give values to be expected on a monthly basis. The week is the smallest unit of time used in these programs and a weekly total of one inch could have fallen in a 30-minute period, or gently over several days. These studies show the probability of receiving selected amounts of precipitation during a given period and location. Other studies give return periods for one to seven day rainfall amounts, while extreme rainfall values have been computed for many locations.

Although the state of the soil is not, strictly speaking, a climatic factor, it can be a definite constraint to the application of wastewater. Prolonged rainy spells can saturate the ground in some areas for up to several weeks. Storage will normally be adequate to handle such events if the rains occur during the summer or fall; however, a prolonged period of heavy rain immediately following the spring thaw could extend the run of unfavorable days and, therefore, increase the amount of storage needed.

It may be of interest to note that Holt, Missouri holds the world's record for the greatest 42 minute rainfall. On June 22, 1947, 12 inches of rain fell in that time period. Thrall, Texas holds the U. S. unofficial 12-hour rainfall record of 32 inches which fell on September 9, 1921. No one would be expected to design for such rare events as these and climatological information can be provided that will permit design of a system with an acceptable built-in risk factor. (See Appendix E.)

Precipitation frequency maps may be obtained from the Office of Hydrology, National Weather Service, National Oceanic and Atmopsheric Administration, Silver Spring, Maryland 20910.

SECTION VIII

EVAPORATION

Weather conditions which restrict operation of wastewater treatment plants have been defined elsewhere in this report. Storage of the effluent may be necessary for a period of from 10 to 180 days. The length of the storage period is usually greatest in the areas where evaporation is at a minimum (climatic zones D, E) and the least in areas of relatively high evaporation (climatic zones A, B, C). Although evaporation can be of primary importance during the time wastewater is being applied, it appears to be of limited importance in estimating storage requirements due to climatic constraints. The estimated capacity of reservoirs in zones D and E could not be reduced significantly because of loss through evaporation during the winter months. In zones A, B, and C storage due to climatic constraints will be needed for relatively short periods, perhaps 10 to 30 days. A detailed study of the expected loss through evaporation at those sites might reduce storage needs slightly.

Pan and lake evaporation values are available in a series of climatic maps of the United States.[17,23] The reliability of the maps is obviously poorer in the areas of high relief than in the plains region and the density of the observation network is an important factor in the series. In addition, the effect of topography has been considered only in a general way except where the data provided definite information. There is a considerable difference between the evaporation from a pan four feet in diameter and 10 inches deep and that from a large reservoir. Estimates indicate that evaporation from reservoirs averages about 30% less than that measured from Class A pans. (See Appendix F.)

This report is primarily concerned with estimating storage needed due to climatic constraints. An important related problem is one of storing wastewater during the off-season for irrigation during the growing season. In this case, the estimated water loss is an important factor in reservoir design.

SECTION IX

SNOWFALL

Snowfall distributions exhibit wide variation whether one considers a 24-hour period, a single storm, a calendar month, or an entire season (Figure 4). Extremes of seasonal snowfall (1930-1970) are listed below for a few selected stations to show this variation. Hartford, Connecticut recorded 83 inches during the 1966-67 season, but had only 15 inches during the 1936-37 season; while Sandburg, California had 101 inches during the 1943-44 season and only 2 inches during the 1934-35 season.

Maps and tables of monthly and seasonal snowfall have been prepared for most of the stations reporting this element. Generalized maps showing the greatest 24-hour snowfall and the greatest monthly snowfall of record are presented in Appendix G. Summaries are also available which give the greatest daily, monthly and annual snowfall. (See Appendix C.) The amounts shown in the examples may not agree due to the use of different periods of record.

	24 Hours	Single storm	Calendar month	Season
ALABAMA	19.2 Florence 12/31–1/1/64	19.5 Florence 12/31–1/1/64	24.0 Valley Head 1/40	25.0 Valley Head 1939–40
ALASKA	62.0 Thompson Pass 12/29/55	175.4 Thompson Pass 12/26–31/55	297.9 Thompson Pass 2/53	974.4 Thompson Pass 1952–53
ARIZONA	38.0 Heber R.S. 12/14/67	67.0 Heber R.S. 12/13–16/67	104.8 Flagstaff 1/49	226.7 Hawley Lake 1967–68
ARKANSAS	25.0 Corning 1/22/18	25.0 Corning 1/22/18	48.0 Calico Rock 1/18	61.0 Hardy 1917–18
CALIFORNIA	60.0 Giant Forest 1/18–19/33	149.0 Tahoe 1/11–17/52	390.0 Tamarack 1/11	884.0 Tamarack 1906–07
COLORADO	75.8 Silver Lake 4/14–15/21	141.0 Ruby 3/23–30/99	249.0 Ruby 3/99	779.0 Ruby 1896–97
CONNECTICUT	28.0 New Haven 3/12/88	50.0 Middletown 3/11–14/88	73.6 Norfolk 3/56	177.4 Norfolk 1955–56
DELAWARE	24.0 Milford 2/12–13/99 24.0 Dover 12/25–26/09	25.0 Milford 12/25–26/09	36.0 Milford 2/99	49.5 Wilmington 1957–58
LORIDA	4.0 Milton Exp. Stat. 3/6/54	4.0 Milton 3/6/54	4.0 Milton 3/54	4.0 Milton 1953–54
GEORGIA	19.3 Cedartown 3/2–3/42	19.3 Cedartown 3/2–3/42	26.5 Diamond 2/95	39.0 Diamond 1894–95
IDAHO	30.0 Pierce R.S. 12/28/68	60.0 Roland W. Portal 12/25–27/37	143.8 Burke 1/54	441.8 Roland W. Portal 1949–50
ILLINOIS	36.0 Astoria 2/27–28/00	37.8 Astoria 2/27–28/00	47.0 Astoria 2/00	77.0 Chicago 1969–70
INDIANA	20.0 Evansville 1/14/18 20.0 La Porte 2/12/44	37.0 LaPorte 2/14–19/58	59.8 La Porte 2/58	122.3 La Porte 1962–63
IOWA	21.0 Sibley 2/18/62	30.8 Rock Rapids 2/17–21/62	42.0 Osage, Northwood 3/15	90.4 Northwood 1908–09
KANSAS	26.0 Fort Scott 12/28–29/54	37.0 Olathe 3/23–24/12	55.9 Olathe 3/12	82.1 Olathe 1911–12
KENTUCKY	18.0 Bowling Green 3/9/60 18.0 Cecilia 11/2/66	27.0 Bowling Green 3/7–11/60	46.5 Benham 3/60	108.2 Benham 1959–60
LOUISIANA	24.0 Rayne 2/14–15/95	24.0 Rayne 2/14–15/95	24.0 Rayne 2/95	24.0 Rayne 1894–95
MAINE	35.0 Middle Dam 11/23/43	56.0 Long Falls Dam 2/24–28/69	88.3 Long Falls Dam 2/69	238.5 Long Falls Dam 1968–69
MARYLAND	31.0 Clear Spring 3/29/42	36.0 Edgemont 3/29–30/42	58.0 Oakland 1/95	174.9 Deer Park 1901–02
MASSACHUSETTS	28.2 Blue Hill 2/24–25/69	47.0 Peru 3/2–5/47	78.0 Monroe 2/93	162.0 Monroe 1892–93
MICHIGAN	27.0 Dunbar 3/29/47 27.0 Ishpemig 10/23/29	46.1 Calumet 1/15–20/50	115.3 Calumet 1/50	298.3 Herman 1968–69
MINNESOTA	28.0 Pigeon R. Bridge 4/4–5/33	35.2 Duluth 12/5–8/50	66.4 Collegeville 3/65	147.5 Pigeon R. Bridge 1936–37
MISSISSIPPI	18.0 Mt. Pleasant 12/23/63 18.0 Tunica 12/23/63	18.0 Mt. Pleasant 12/23/63 18.0 Tunica 12/23/63	23.0 Cleveland 1/66	25.2 Senatobia 1967–68
MISSOURI	27.6 Neosho 3/16–17/70	27.6 Neosho 3/16–17/70	47.5 Poplar Bluff 1/18	70.3 Maryville 1911–12
MONTANA	30.0 Summit 10/29/51	46.0 Summit 3/31–4/3/54	123.0 Summit 1/54	406.5 Kings Hill 1958–59
NEBRASKA	24.0 Hickman 2/11/65	41.0 Chadron 1/2–4/49	59.6 Chadron 1/49	104.9 Kimball 1958–59
NEVADA	25.0 Mt. Rose Resort 1/20/69	75.0 Mt. Rose Resort 1/18–22/69	124.0 Mt. Rose Resort 1/69	323.0 Mt. Rose Resort 1968–69
NEW HAMPSHIRE	56.0 Randolph 11/22–23/43	77.0 Pinkham Notch 2/24–28/69	130.0 Pinkham Notch 2/69†	323.0 Pinkham Notch 1968–69†
NEW JERSEY	29.7 Long Branch 12/26–27/47	34.0 Cape May 2/11–14/99	50.1 Freehold 12/80	108.1 Culver Lake 1915–16
NEW MEXICO	30.0 Sandia Crest 12/29/58	40.0 Corona 12/14–16/59	144.0 Anchor Mine 3/12	483.0 Anchor Mine 1911–12
NEW YORK	45.0 Watertown 11/14–15/00	69.0 Watertown 1/18–22/40	120.0 Old Forge 3/71	375.0 Old Forge 1970–71
NORTH CAROLINA	31.0 Nashville 3/2/27	31.0 Nashville 3/2/27	56.5 Boone 3/60	100.7 Banner Elk 1959–60
NORTH DAKOTA	24.0 Lisbon 2/15/15 24.0 Berthold Agency 2/25/30	35.0 Lisbon 2/13–15/15	45.5 Tagus 4/70	99.9 Pembina 1906–07
OHIO	20.7 Youngstown 11/24–25/50	36.3 Steubenville 11/24–26/50	69.5 Chardon 12/62	161.5 Chardon 1959–60
OKLAHOMA	23.0 Buffalo 2/21/71	36.0 Buffalo 2/21–22/71	39.5 Buffalo 2/71	87.3 Beaver 1911–12
OREGON	37.0 Crater Lake 1/17/51	95.0 Crater Lake 1/15–19/51	256.0 Crater Lake 1/33	879.0 Crater Lake 1932–33
PENNSYLVANIA	38.0 Morgantown 3/20/58	50.0 Morgantown 3/19–21/58	86.0 Blue Knob 12/90	225.0 Blue Knob 1890–91
RHODE ISLAND	34.0 Foster 2/8–9/45	34.0 Foster 2/8–9/45	62.0 Foster 3/56	122.6 Foster 1947–48
SOUTH CAROLINA	21.8 Caesar's Head 2/16/69	28.9 Caesar's Head 2/15–16/29	33.9 Caesar's Head 2/69	60.3 Caesar's Head 1968–69
SOUTH DAKOTA	38.0 Dumont 3/27/50	60.0 Dumont 3/26–28/50	94.0 Dumont 3/50	222.7 Lead 1969–70
TENNESSEE	22.0 Morristown 3/9/60	28.0 Westbourne 2/19–21/60	39.0 Mountain City 3/60	75.5 Mountain City 1959–60
TEXAS	24.0 Plainview 2/3–4/56	33.0 Hale Center 2/2–5/56	36.0 Hale Center 2/56	65.0 Romero 1923–24
UTAH	35.0 Kanush 2/9/53	64.0 Alta 12/2–7/51	165.0 Alta 3/48	663.0 Alta 1951–52
VERMONT	33.0 St. Johnsbury 2/25/69	50.0 Readsboro 3/2–6/47	75.0 Waitsfield†	197.5 Waitsfield†
VIRGINIA	33.0 Big Meadows 3/6/62	42.0 Big Meadows 3/6–7/62	54.0 Warrenton 2/99	98.0 Mountain Lake 1913–14
WASHINGTON	52.0 Winthrop 1/21/35	129.0 Laconia 2/24–26/10	363.0 Paradise R.S. 1/25	1027.0 Paradise R.S. 1970–71
WEST VIRGINIA	34.0 Bayard 4/27–28/28	57.0 Pickens 11/23–30/50	97.0 Pickens 2/47	266.2 Pickens 1959–60
WISCONSIN	26.0 Neillsville 12/27/04	30.0 Racine 2/19–20/98	80.5 Gurney 12/68	230.0 Gurney 1968–69
WYOMING	34.0 Bechler River 1/28/33	52.0 Bechler River 1/15–19/37	188.5 Bechler River 1/33	491.6 Bechler River 1932–33

(Measurements are inches of snowfall)

† Figures have been exceeded at mountain top stations.

Source: Ludlum, D.M., "Weather Record Book - the Outstanding Events 1871-1970"

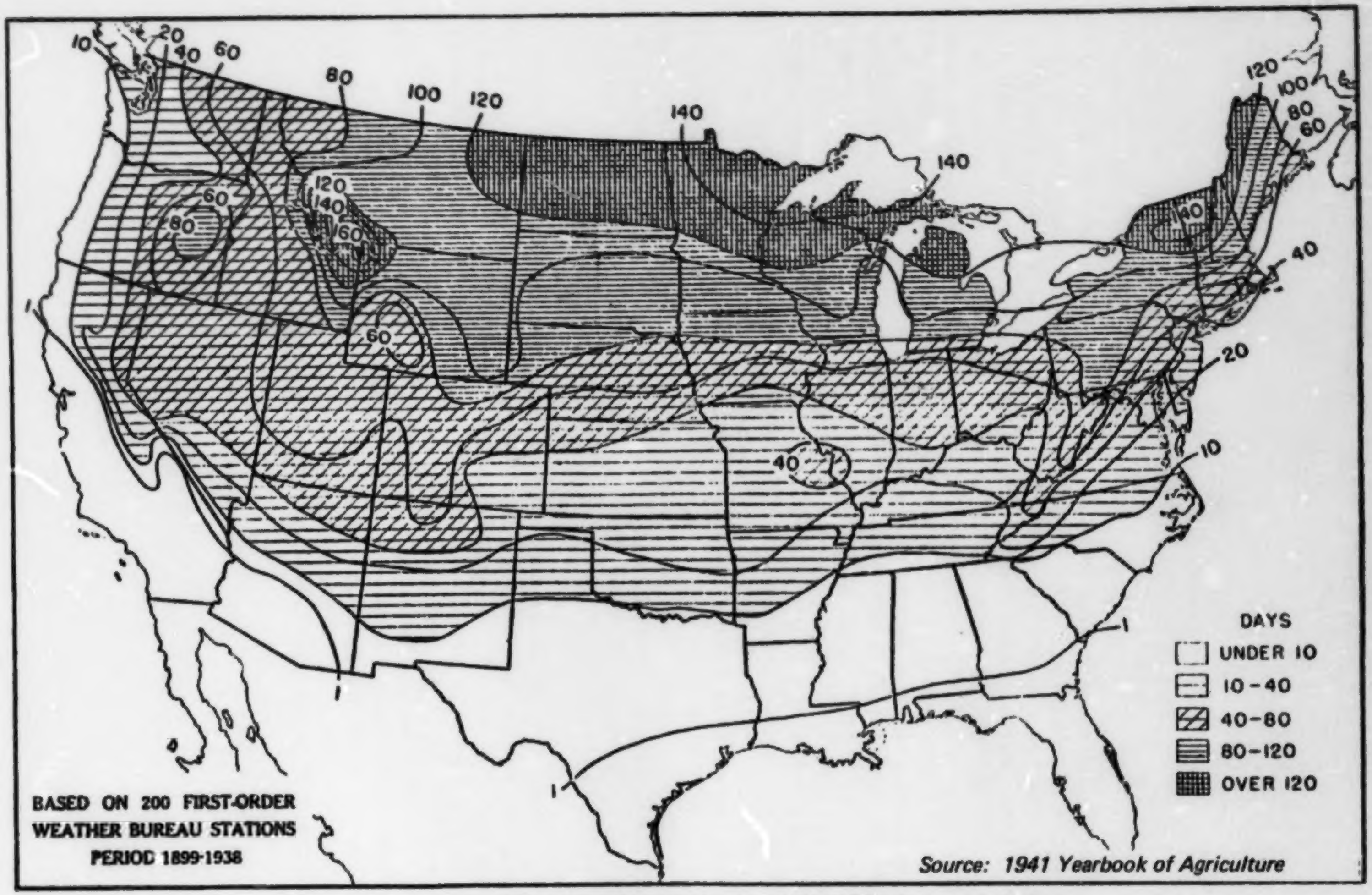
Fig. 4 Extremes of snowfall by states

SECTION X

SNOW DEPTH

Numerous studies have been made of the relationship between snow cover and frost penetration.[2,4,5,24,28,30] Crawford[14] states that on the average the frost depth is reduced about two feet for each foot of snow cover, while others report that snow reduced frost penetration by an amount equal to its depth. Baker[3] concludes that examination of the type of winter (snow depth and duration) with cumulative growing degree days proved to be a simple and effective means of predicting the maximum freezing depth. Baker also states, "the period when liquid water is restricted in movement through the soil is of obvious importance." This is defined as the period extending from the time when the temperature (at the 5 cm. depth) remained less than 32°F until the 32°F isotherm completely disappeared from the soil. The commencement date of this period was selected to ensure that water was in solid form and that soil was frozen sufficiently to serve as an effective barrier to surface water. The mean commencement date of this period at St. Paul, Minnesota was December 1 and the mean termination date was April 16. Thus, the mean duration was 136 days and over the eight years he examined ranged from 118 to 166 days. It is interesting to note that the Freezing Index program gives a mean of 124 days, while the value expected to be exceeded 10% of the time is 142 days.

Maps showing the depth of snow on the ground at 0700 EST each Monday during the winter months are published in the Weekly Weather and Crop Bulletin.[36] A map of the average annual number of days with snow cover one inch or more is presented in Figure 5. In addition, maps showing the maximum water equivalent, in inches, have been published in the U. S. Weather Bureau Technical Paper #50.[32] They show the maximum water equivalent for selected periods (i.e., March 1-15) expected to be equaled or exceeded once in two years, once in 25 years, etc. (selected probability levels). These can be useful in estimating soil moisture and stream flow in the Midwest during the spring months.



10
20
40
60
80
100
120
140
140
120
100
80
60
40
20
10
1
120
140
160
60
80
60
140
40
1
1
1
DAYS
☐ UNDER 10
▤ 10-40
▨ 40-80
▤ 80-120
▦ OVER 120
BASED ON 200 FIRST-ORDER
WEATHER BUREAU STATIONS
PERIOD 1899-1938

Source: 1941 Yearbook of Agriculture

Fig. 5 Average annual number of days with snow cover 1.00 inch or more in depth

SECTION XI

WIND DIRECTION AND SPEED

Analysis of wind speed and wind direction can be provided in many ways as shown in Appendix I. Maps have been prepared which show the prevailing direction and speed on a monthly basis for the United States. While this information can be useful, the design engineer may be more interested in the occurrence of high wind speeds from certain sectors. In spray irrigation, for example, high winds might be acceptable only from a certain quadrant. In addition, the duration and frequency of such events may be of special interest. Processing the observed data can provide probabilities, or the likelihood of certain conditions occurring during those months when spraying is at a peak. The wind pattern is of particular interest [35] where municipal wastewater is applied by spraying and aerosol drift is a problem of significant concentration. In addition, prevailing wind direction, especially during the warm months, should be considered if odor is a problem.

Stations in the National Weather Service routinely report hourly wind direction and speed. Most of these stations also report the daily peak gust, along with its direction and time of occurrence. Special summaries can be prepared for those areas where more detailed wind information is available.

SECTION XII

AIR TEMPERATURE

Hourly and daily temperatures are recorded at most of the stations operated by the National Weather Service, while only daily measurements are taken at the cooperative stations. The mean of the daily maximum and minimum temperatures measured in a shelter about six feet above the ground is the average daily temperature. Although some stations compute daily averages for a 24-hour period ending at midnight and other stations use a different 24-hour period (8 a.m. to 8 a.m.), either type can be used in the programs discussed in this report.

Any combination of freezing air temperatures, frozen ground or the presence of snow and ice can result in ice formation from at least part of the applied liquid. A frozen surface reduces (or prevents) the infiltration of the effluent which leads to ponding and/or runoff which can cause severe erosion.[34]

A wide assortment of temperature summaries, maps,[16] etc., have been prepared as shown in Appendix J. Tables showing the average dates of the last freezing temperature in the spring and the first in the fall are available in several publications[18,36] and provide information on the length of the growing season.

SECTION XIII

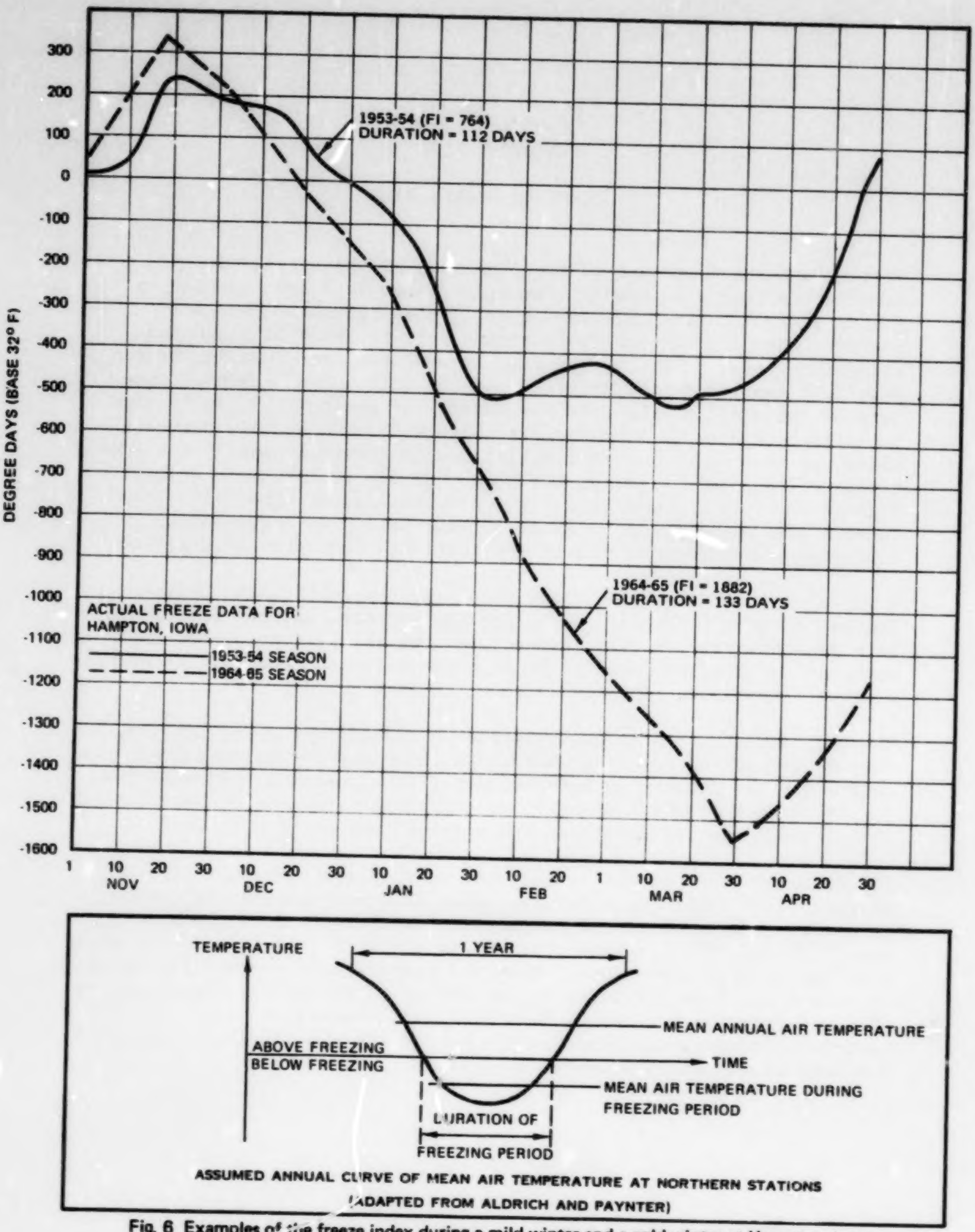
FREEZING DEGREE DAYS

Degree Days are a measure of the departure of the average daily temperature from a standard. Freezing degree days are computed by subtracting 32°F from the average daily temperatures. They are positive when the average daily temperature is above 32°F and negative when below 32°F. Degree days accumulated over a winter season provide a measure of the intensity of the cold. The length of time between the onset of the cold period and the spring thaw can be used in estimating storage requirements (Figure 6). Degree day accumulations are obtained for each freezing season (November-April) and the Freezing Index is defined as the number of degree days between the highest and lowest point on a curve plotted against time.[4,26] The indexes are averaged over a 20 to 30 year period and probability tables can be prepared for both the intensity (FI) and the duration.

A map of mean air Freezing Index values in the continental United States is shown in Figure 7. Notice the expected general agreement with maps of daily average temperature, the climatic zones for land application, average depth of frost penetration and the 10th percentile minimum temperature for January shown in Appendix J.

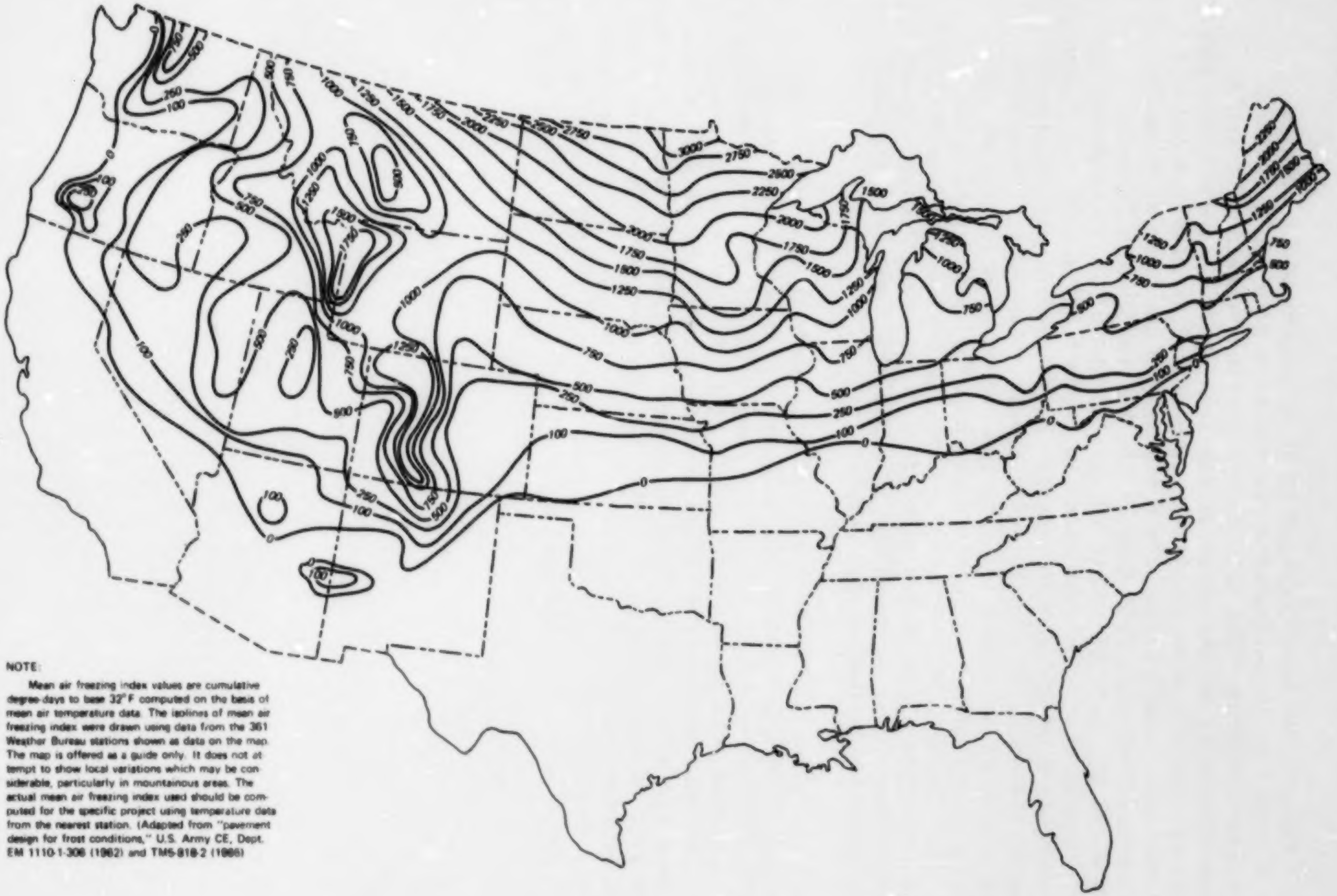
Missing temperature data can introduce a significant error into the computation of the Freezing Index. An inventory of the digitized record for the station is examined prior to processing. If more than four days records are missing in an individual year-month the data for that station are not processed and a substitute station is used.

The Freezing Index should be computed only at stations where the average daily temperature remains below 32°F for at least two weeks. As a rule, the index can be computed for all stations in climatic zones "D" and "E"; for some stations in zones "B" and "C" and for most stations at high elevations. When the temperatures are not low enough to obtain the Freezing Index an estimation of the storage needs may be obtained from the periods of Favorable and Unfavorable days. Monthly normals of temperature based on the period 1941-70 have been published for each state [9] and are useful in planning.



ASSUMED ANNUAL CURVE OF MEAN AIR TEMPERATURE AT NORTHERN STATIONS
(ADAPTED FROM ALDRICH AND PAYNTER)

Fig. 6 Examples of the freeze index during a mild winter and a cold winter at Hampton, Iowa



NOTE:

Mean air freezing index values are cumulative degree-days to base 32° F computed on the basis of mean air temperature data. The isolines of mean air freezing index were drawn using data from the 361 Weather Bureau stations shown as data on the map. The map is offered as a guide only. It does not attempt to show local variations which may be considerable, particularly in mountainous areas. The actual mean air freezing index used should be computed for the specific project using temperature data from the nearest station. (Adapted from "pavement design for frost conditions," U.S. Army CE, Dept. EM 1110-1-306 (1962) and TM5-818-2 (1966)

Fig. 7 Distribution of mean air freezing index values in the continental United States

A special feature has been included in this program which permits greater flexibility in determining the duration of a "cold period" in the milder climates. The mild days occurring between cold spells can be considered as an extension of the cold spell. In addition, the intensity of the mild days (Positive Degree Days) is examined and the episode continued until either the duration, or the intensity reaches fixed threshold values. This feature can be seen in the listings (Figures 8, 9, 10, and 11) and is especially useful in areas where the mean temperature of the coldest month is between 28° and 34°F. A mean daily temperature of 33° and 34° may not be considered significant in breaking a cold spell if it persists for only a few days. Requesters have the option of setting a limit on the number of mild days as well as on the maximum number of degree days observed during this mild period. For example, if a cold period lasting twelve days was followed by three days when the positive cumulative degree days did not exceed 6 and low temperatures returned for an additional ten days, the total duration would be defined as 25 days.

An example is given in Figure 9 of a station in a mild climate where the greatest Freezing Index is not selected for a particular season. The modified threshold of 4 days, or 8 cumulative degree days has been used to continue cold spells which would otherwise be ended by a warm period. The cold period of greatest duration during the 1960-61 season ran 28 days (from December 8, 1960 to January 5, 1961) and had a Freezing Index of 171. A more intense (FI=266), but shorter (20 days) cold spell occurred between January 18 and February 7, 1961. The modified program is thereby designed to select the longest cold period rather than the one with the largest Freezing Index.

SECTION XIV

FAVORABLE AND UNFAVORABLE DAYS FOR OPERATION

The Freezing Index can be a useful guide in estimating storage requirements for stations in cold climates, but is not designed for locations where the average daily temperature remains above 32°F. For stations whose monthly normal temperature during January is around 30°F, an examination of the Favorable-Unfavorable days is more useful. The constraints to operation are assumed to be average daily temperature 32°F or less; snow depth 1.00 inch or more, or daily precipitation greater than 0.50 inch. These thresholds are flexible depending on the definition of non-operating conditions for the system being considered. The occurrence of fog or high winds might be a constraint for a short period, but neither is likely to be of significance except in isolated cases. Daily weather observations for a 20 to 30-year period are scanned by the computer and each day is classed as Favorable or Unfavorable according to the previously mentioned criteria. The number of days in sequence for each condition is printed each time the sequence is broken.

If a system is designed for twelve months operation, storage needs can be estimated by converting the number of Unfavorable days into days of storage. The estimated daily volume to be distributed is then reduced according to the number of Favorable days. This is necessary since, when irrigation begins, the current daily flow must be used as well as the stored volume. This cumulative cycle is continued through each winter season to determine the maximum number of days when storage is required based upon the assigned threshold criteria. The example in Figure 8 uses thresholds of (1.00) for an Unfavorable day and minus one-half (-0.50) for Favorable days. The greatest accumulated value is printed out at the end of each season and in Table 1 as MAX STOR. Examination of the frequency distribution of the length of runs of Favorable-Unfavorable periods is also recommended (Figures 8, 9, 10, and 11).

The marginal areas between distinct climatic zones present the greatest challenge in estimating the climatic constraints and the associated storage requirements. Over-estimating storage needs will result in excessive costs. If the estimated storage is insufficient, the operational problems are obvious. For such cases, the extreme conditions could be examined to discover their frequency and intensity as well as the ensuing consequences of such events.

The Favorable-Unfavorable day (FA-UNF) program has been used to process climatological data for a number of stations. Data for Pauls Valley, which lies in South Central Oklahoma, is an example of a location where the normal temperature for the coldest month is above 32°F and the FA-UNF portion of the program should be utilized. Although the maximum number of UNF days is given, the exact distribution of FA-UNF days is not obvious from the tables. Several runs of UNF (storage) days may be broken by short spells of FA (operating) days. In order to take into account those days when operation could take place, the following procedure was initiated. An assumed storage volume (1 unit) was assigned to each day defined as UNF. It was further assumed that during FA days of operation the system could disperse an amount equal to one and one-half units. Therefore, a one is added in the storage counter for each UNF day and a one-half is subtracted for each FA day. This cumulative count (MAX STOR) is continued through each individual season and the largest number is thus an estimate of the number of days storage would be required based upon the defined thresholds. At the end of each season and period of record these values are listed and percentiles are computed. This method of accounting results in a more reliable estimate of storage requirements than obtained from relying only on the maximum number of UNF days.

JOB NO. 14843

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS

Listing of Daily Weather Observations

PERIOD OF RECORD:

STA:	
YR:	49 = 1949, etc.
MO:	01 = Jan., etc.
DA:	01-31
MAX:	daily maximum temperature (°F)
MIN:	daily minimum temperature (°F)
MEAN:	daily mean temperature (°F)
SNOW DEPTH:	depth of snow on the ground at observation time. T = trace
PPPP:	total daily precipitation amount, inches and hundredths (T = trace)
FOG:	an "F" in this column means that fog occurred on the indicated date
DD:	daily degree days to base 32°F, computed by subtracting 32 from the daily mean temperature (DMT) i.e., DD = DMT - 32
CDD:	the cumulative degree days provide a measure of coldness. As the winter becomes colder the CDD's change from positive to negative (or decrease). The difference between the extreme values is a measure of the intensity of the cold period and is defined as the freeze index. The number of days between these points is the duration of the cold period. Tables of high to low freeze index and percentiles are furnished in Table 1. An option is available which provides for extension of cold periods through short (4 day) warm spells. In addition, the intensity of the warm period determined by the accumulated degree days may not exceed a selected base (currently set at 8).
FA:	favorable day of operation: Mean daily temperature is above 32°F, snow depth is less than 1 inch and total daily precipitation is less than 0.50 inch (all conditions must be met).
UNF:	unfavorable day of operation: Mean daily temperature is 32°F, or less, snow depth is 1", or more, and total daily precipitation is more than 0.49 inch (one or more conditions must be met). Thresholds may change from one station to the next.
DUR FA, UNF:	The numbers here indicate the length of runs (in days).
MAX STOR:	A value of one (1.00)is assigned to each day when storage is required (unfavorable), while a value of minus one-half (-0.50) is given to each day when the system could operate (favorable). These values are accumul[illegible] for each season with the counter reset to a minimum base of zero regardless of the number of favorable day[illegible] a sequence (Figure 9). The maximum values in this column are printed at the end of each season and in Tab[illegible]

Table 1: A summary of the information obtained at the end each season which shows 10, 25, 50, 75 and 90 percentile values along with the average Freeze Index over the period.

Table 2: A distribution of the sequential sets of unfavorable-favorable days shown in the listings. For example, a run of 12 UNF days followed by a run of 20 FA days makes the set (12-20) and is counted in the third row down (11-15 UNF) and the fourth column (16-20 FA) from the left.

Fig. 8 Description of chronological listing shown in Fig. 9

```
USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS                             01/08/75
STA #  937210   BALTIMORE, MD (FRIENDSHIP AP)                       POR: 501101-720430
                             SNOW                                    DUR           DUR     MAX
YR  MO  DA  MAX   MIN  MEAN  DPTH    PPPP  FOG     DD    CDD   FA     FA   UNF     UNF    STOR

60  12  01   40    28    34                         2    456    X
60  12  02   43    22    33                         1    457    X
60  12  03   53    26    40                         8    465    X
60  12  04   58    23    41                         9    474    X
60  12  05   64    34    49                        17    491    X
60  12  06   65    30    48                        16    507    X
60  12  07   55    34    45                        13    520    X
60  12  08   42    27    35                         3    523    X
60  12  09   33    13    23                        -9    514          38    X              1.0
60  12  10   49    12    31                        -1    513                X              2.0
60  12  11   39    23    31          1.12  F       -1    512                X              3.0
60  12  12   24    14    19    12     .53  F      -13    499                X              4.0
60  12  13   19     8    14     9                 -18    481                X              5.0
60  12  14   33    11    22     7                 -10    471                X              6.0
60  12  15   33     9    21     6          F      -11    460                X              7.0
60  12  16   42    24    33     5     .01  F        1    461                X              8.0
60  12  17   37    14    26     5                  -6    455                X              9.0
60  12  18   34    10    22     3                 -10    445                X             10.0
60  12  19   38     8    23     2          F       -9    436                X             11.0
60  12  20   31    10    21     2                 -11    425                X             12.0
60  12  21   37    21    29     2     .41  F       -3    422                X             13.0
60  12  22   21     4    13     2                 -19    403                X             14.0
60  12  23   26     0    13     2                 -19    384                X             15.0
60  12  24   24    11    18     2                 -14    370                X             16.0
60  12  25   42    12    27     2                  -5    365                X             17.0
60  12  26   50    16    33     2          F        1    366                X             18.0
60  12  27   44    22    33     1                   1    367                X             19.0
60  12  28   26    15    21     1                 -11    356                X             20.0
60  12  29   33    24    29     2     .84  F       -3    353                X             21.0
60  12  30   39    24    32                F        0    353                X             22.0
60  12  31   37    20    29     1     .01  F       -3    350                X             23.0
```

Fig. 9 Chronological listing of daily weather observations for Baltimore, Md. for Dec. 1960 with computed values

```
USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS                       01/08/75
STA #  937210   BALTIMORE, MD (FRIENDSHIP AP)                        POR: 501101-720430
                        HIGH TO LOW FREEZE INDEX
                              DATE                 MAX     MAX    MAX
                INDX    BEGIN        END      DUR    FA     UNF   STOR

                 217    660107     660209      33    29      23   37.0
                 188    621208     630105      28    34      22   54.0
                 171    601208     610105      28    38      30   54.5
                 171    671222     680117      26    36      22   24.5
                 149    631213     640101      19    20      20   34.5
                 144    580207     580221      14    19      24   36.0
                 118    600229     600316      16    25      17   25.0
                 117    691231     700116      16    16      11   34.0
                 112    581205     581222      17    28      13   31.5
                 104    570110     570120      10    25       7   13.5
                  99    550126     550205      10    30       5   19.0
                  94    650110     650121      11    35      14   26.5
                  79    510129     510210      12    24       7   21.0
                  69    551209     551223      14    23      14   32.5
                  62    540110     540118       8    33       8   11.5
                  62    670216     670301      13    28      11   28.0
                  59    681229     690108      10    34       8   23.0
                  58    511212     511219       7    17       8   10.5
                  55    620206     620221      15    19      14   50.0
                  41    720203     720210       7    22      12   20.0
                  35    701224     710101       8    24      17   35.0
                   8    521226     521229       3    17       5    7.5

AVERAGE INDEX    101


PERCENTILES
10%              183                           28                 53.0
25%              145                           17                 35.2
50%               96                           13                 27.2
75%               59                            9                 19.7
90%               37                            7                 10.8
```

Fig. 10 Seasonal values of the freezing index, as indicated, with percentiles

```
                USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS                                   01/08/75
                STA #  937210    BALTIMORE, MD (FRIENDSHIP AP)                               POR: 501101-720430
UNFAVORABLE                                FAVORABLE   DAYS   OF   OPERATION
 DAYS  OF       1-    6-   11-   16-   21-   26-   31-   36-   41-   46-   51-   56-   61-   66-   71-   76-   81-   86-   91-   96-  100+
OPERATION       5    10    15    20    25    30    35    40    45    50    55    60    65    70    75    80    85    90    95   100

   1-5        246    72    39    18     7     3     4     1

   6-10        21     5
                                  ①
  11-15         9

  16-20         1     2

  21-25         3     2

  26-30         1

  31-35

  36-40

  41-45

  46-50

  51-55

  56-60

  61-65

  66-70

  71-75

  76-80

  81-85

  86-90

  91-95

  96-100

  100+
```

Fig. 11 Distribution of sets of UNF-FA days of operation

SECTION XV

REFERENCES

1. Aldrich, H. P., Jr. and Paynter, H. M., "Depth of Penetration in Non-Uniform Soil," Special Report 104, U. S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire (October 1966). 11 p.

2. Atkinson, H. B. and Bay, E. E., "Some Factors Affecting Frost Penetration," Transactions, American Geophysical Union, Vol. 21, Part 3B, pp 935-947 (September 1940).

3. Baker, D. G., "Snow Cover and Winter Soil Temperatures at St. Paul, Minnesota," Water Resources Research Center, Minneapolis, Minnesota (June 1971). 16 p.

4. Bigelow, N., Jr., "Freezing Index Maps of Maine," Technical Paper 69-5R, Materials and Research Division, Maine State Highway Commission (September 1969). 20 p.

5. Boyd, D. W., "Normal Freezing and Thawing Degree Days for Canada (1931-1960)," Atmospheric Environment Service, Department of Environment, Downsview, Ontario, Canada (1973). 40 p.

6. "Climate and Man," Yearbook of Agriculture, U. S. Department of Agriculture, Washington, D. C. (1941). 1248 p.

7. "Climatic Atlas of the United States," U. S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Washington, D. C. (June 1968). 80 p.

8. "Climatological Data, National Summary," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, North Carolina (1973). 114 p.

9. "Climatography of the U. S. No. 81, Monthly Normals of Temperature, Precipitation and Heating and Cooling Degree Days, 1941-70 (by State)," U. S. Department of Commerce, National Climatic Center, Asheville, North Carolina (August 1973). 250 p.

10. "Climatography of the United States, No. 82, Summary of Hourly Observations," U. S. Department of Commerce, U. S. Weather Bureau, Washington, D. C. (1963). 15 p.

11. "Climatography of the United States, No. 84, Daily Normals of Temperature and Heating and Cooling Degree Days, 1941-70," U. S. Department of Commerce, National Climatic Center, Asheville, North Carolina (September 1973). 650 p.

12. "Climatography of the United States, No. 85, Monthly Averages of Temperature and Precipitation for State Climatic Divisions 1941-70, U. S. Department of Commerce, National Climatic Center, Asheville, North Carolina (July 1973). 150 p.

13. "Compendium of Meteorology," edited by Thomas F. Malone, American Meteorological Society, Boston, Massachusetts (1951). 1334 p.

14. Crawford, C. B., "Construction on Permafrost," Division of Building Research, National Research Council, Ottawa, Canada.

15. Decker, W. L., "Periods with Temperatures Critical to Agriculture," North Central Regional Research Publication No. 174, University of Missouri Agricultural Experiment Station, Columbia, Missouri (1967). 76 p.

16. Doner, J. P., "A Predictive Study for Defining Limiting Temperatures and Their Application in Petroleum Product Specifications," U. S. Army, Mobility Equipment Research and Development Center, Coating and Chemical Laboratory, Aberdeen Proving Ground, Maryland (1972). 176 p.

17. "Extreme Maximum Values of Evaporation at Selected Stations in Eleven Western States and Texas," Bulletin 761, Washington Agriculture Experiment Station, College of Agriculture, Pullman, Washington (October 1972). 32 p.

18. "Freezing Temperature in Oklahoma," Oklahoma State University Extension Center, Stillwater, Oklahoma (undated). 23 p.

19. Jessberger, H. L., "Ground Frost: A Listing and Evaluation of More Recent Literature Dealing with the Effect of Frost on the Soil," U. S. Army Foreign Science and Technology Center, U. S. Army Material Command, Washington, D. C. (February 1970). 500 p.

20. "Local Climatological Data, Annual Summary with Comparative Data," U. S. Department of Commerce, National Climatic Center, Asheville, North Carolina (1973).

21. Ludlum, D. M., "Weather Record Book-The Outstanding Events 1871-1970," Weatherwise, Inc., Princeton, N. J. (1971). 98 p.

22. "Muskegon County Plan for Managing Wastewater," Bauer Engineering Co., Chicago, Illinois (1969).

23. "National Atlas of the United States," Hydrologic Services Division, U. S. Weather Bureau, Washington, D. C. (1966). 417 p.

24. "Pavement Design for Frost Conditions," U. S. Department of Commerce, Superintendent of Documents, Washington, D. C. (1962). 64 p.

25. "Precipiation Probabilities in the North Central States," Bulletin 753, Agricultural Experiment Station, University of Missouri, Columbia, Missouri (June 1960). 72 p.

26. "Prediction of Freezing Temperature Penetaration in New England," Miscellaneous Paper II, Arctic Construction and Frost Effects Laboratory, U. S. Army Corps of Engineers, Boston, Massachusetts (June 1955).

27. "Revised Uniform Summary of Surface Weather Observations, Part B," Unpublished Tabulations, U. S. Department of Commerce, National Climatic Center, Asheville, North Carolina (1973). 6 p.

28. Sanger, F. J., "Computations on Frost in the Ground," Journal of the New England Water Works Association 80 (1): pp 47-67 (1966).

29. Sepp, E., "The Use of Sewage for Irrigation - A Literature Review," Bureau of Sanitary Engineering, Sacramento, California (1971).

30. "Soil Temperature and Ground Freezing," Bulletin 71, Proceedings of the Thirty-Second Annual Meeting of the Highway Research Board, Washington, D. C. (January 1953).

31. "Survey of Facilities Using Land Application of Wastewater, Report No. 430/9-73-006, U. S. Environmental Protection Agency, Washington, D. C. (July 1973). 377 p.

32. "Frequency of Maximum Water Equivalent of March Snow Cover in North Central United States," Technical Paper No. 50, U. S. Weather Bureau, Office of Hydrology, Cooperative Studies Section, Washington, D. C. (1964). 24 p.

33. "The National Climatic Center (NCC)," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D. C. (1970). 34 p.

34. "Wastewater Management by Disposal on the Land," Special Report #171, U. S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire (May 1972). 183 p.

35. "Wastewater Treatment and Reuse by Land Application, Volumes I and II," Report No. 660/2-73-006 a and b, Environmental Protection Technology Series, Office of Research and Development, U. S. Environmental Protection Agency, Washington, D. C. (August 1973). 80 p. and 249 p.

36. "Weekly Weather and Crop Bulletin," U. S. Department of Commerce, U. S. Department of Agriculture, Agricultural Climatology Service Office, Washington, D. C. (1973). 14 p.

37. Wisner, W. M., "Rainfall Frequency Atlas for Missouri," University of Missouri Extension Division, Columbia, Missouri (1973). 32 p.

SECTION XVI

APPENDICES

		Page
A	INTRODUCTION TO APPENDICES	38
B	PRIMARY WEATHER REPORTING NETWORK AND PUBLICATIONS	39
C	COOPERATIVE WEATHER REPORTING NETWORK AND SUMMARIES	43
D	STATE CLIMATIC DIVISIONS AND MONTHLY AVERAGES 1941-70	46
E	PRECIPITATION	48
F	EVAPORATION	50
G	SNOWFALL	52
H	SNOW DEPTH	54
I	WIND DIRECTION AND SPEED	55
J	AIR TEMPERATURE	59
K	MONTHLY AND DAILY NORMALS 1941-70	64
L	OTHER PUBLICATIONS AND UNPUBLISHED TABULATIONS	66

A. INTRODUCTION TO APPENDICES

Examples are presented in the Appendices of some of the many types of published and unpublished summaries of climatological data which may be of interest to those planning Soil Treatment Systems. They have been prepared by a number of organizations and are shown primarily to provide information on the variety of material available. Many of the summaries were developed to fill a need in one particular discipline, e.g., engineering, aviation, agriculture, etc., but can be useful in others.

Special methods sometimes must be designed to fit the needs of a particular problem, as in the case of the Freeze Index and Unfavorable-Favorable Day programs. In all cases, the weather observations have been recorded by several networks to satisfy the public requirements by the most economical means. They occasionally may be less than ideal for answering a specific problem because of incomplete or broken periods of record. Careful examination of basic input data will be a guide as to the degree of confidence one might expect.

The NCC library participates in the Intra-library Loan System with the Library of Congress, universities and other State and Federal Agencies. Copies of all NCC produced computer tabulations of climatological data are indexed and filed for future use. A large part of the Center's holdings are available in the form of microfilm and/or magnetic tape and can also be furnished to users for the cost of duplication.

For easy reference the Appendices B-L are identified in the following pages in the lower right corner.

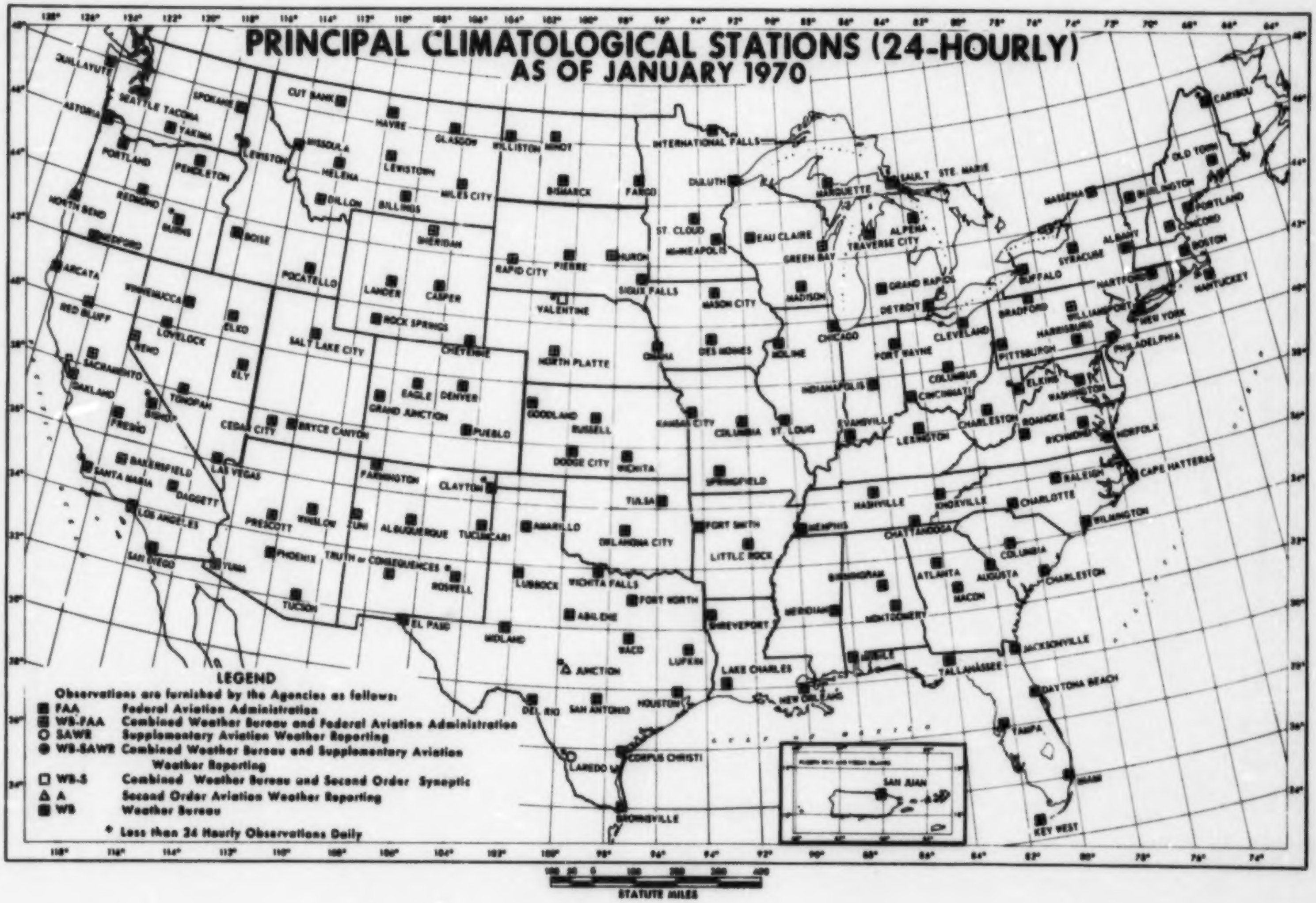
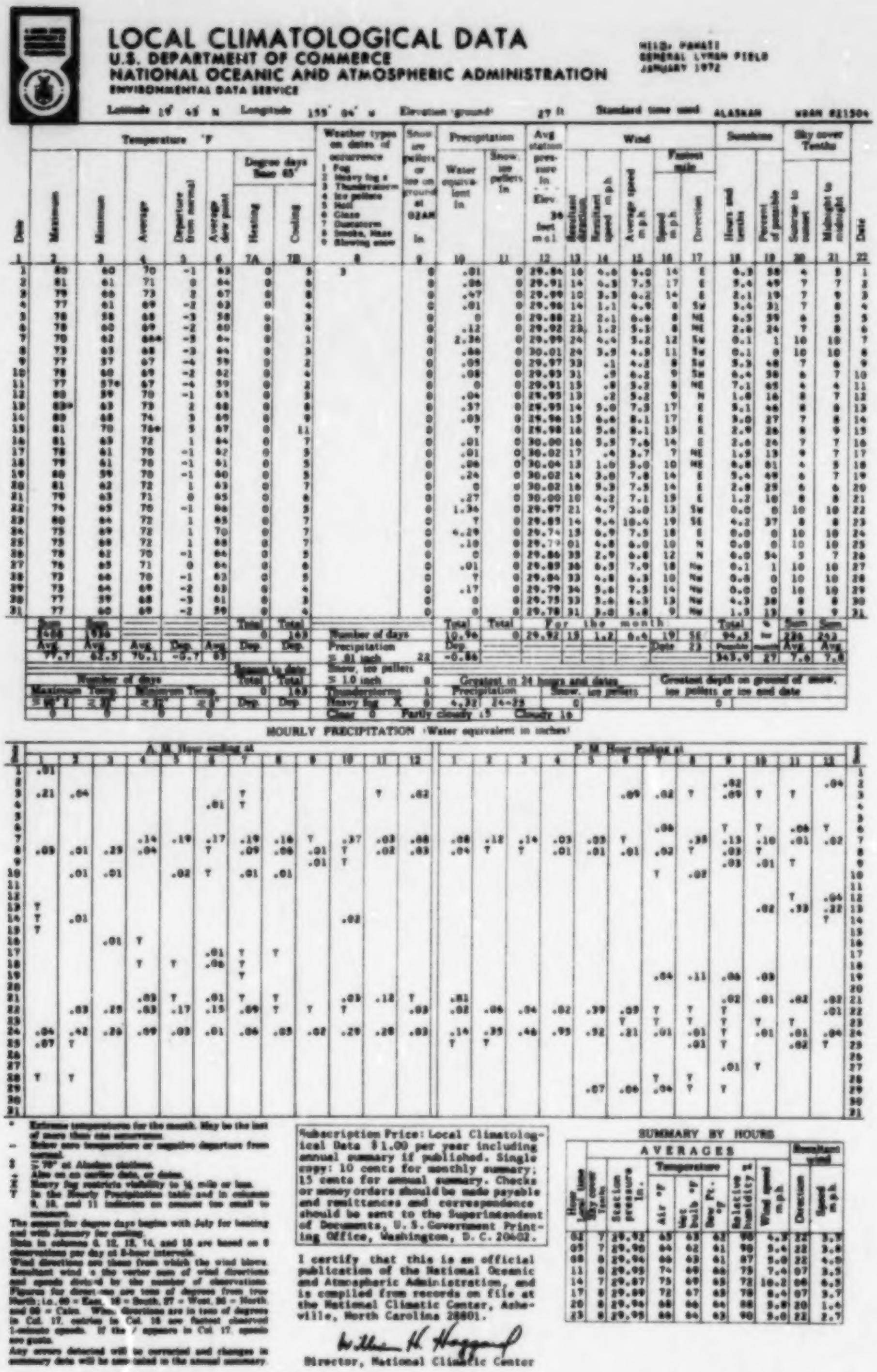

PRINCIPAL CLIMATOLOGICAL STATIONS (24-HOURLY)
AS OF JANUARY 1970
LEGEND
Observations are furnished by the Agencies as follows:
FAA Federal Aviation Administration
WB-FAA Combined Weather Bureau and Federal Aviation Administration
SAWR Supplementary Aviation Weather Reporting
WB-SAWR Combined Weather Bureau and Supplementary Aviation Weather Reporting
WB-S Combined Weather Bureau and Second Order Synoptic
A Second Order Aviation Weather Reporting
WB Weather Bureau
* Less than 24 Hourly Observations Daily
STATUTE MILES
QUILLAYUTE
SEATTLE TACOMA
SPOKANE
YAKIMA
ASTORIA
PORTLAND
PENDLETON
LEWISTON
REDMOND
NORTH BEND
BURNS
MEDFORD
BOISE
CUT BANK
HAVRE
GLASGOW
WILLISTON
MINOT
MISSOULA
HELENA
LEWISTOWN
MILES CITY
DILLON
BILLINGS
BISMARCK
FARGO
INTERNATIONAL FALLS
DULUTH
SHERIDAN
POCATELLO
LANDER
CASPER
ROCK SPRINGS
CHEYENNE
RAPID CITY
PIERRE
HURON
VALENTINE
SIOUX FALLS
ST. CLOUD
MINNEAPOLIS
EAU CLAIRE
GREEN BAY
MARQUETTE
SAULT STE MARIE
ALPENA
TRAVERSE CITY
ARCATA
WINNEMUCCA
RED BLUFF
LOVELOCK
ELKO
RENO
ELY
SALT LAKE CITY
SACRAMENTO
OAKLAND
TONOPAH
BISHOP
FRESNO
CEDAR CITY
BRYCE CANYON
EAGLE
DENVER
GRAND JUNCTION
PUEBLO
NORTH PLATTE
OMAHA
MASON CITY
DES MOINES
MOLINE
MADISON
CHICAGO
GRAND RAPIDS
DETROIT
FORT WAYNE
CLEVELAND
BAKERSFIELD
SANTA MARIA
LAS VEGAS
DAGGETT
LOS ANGELES
SAN DIEGO
YUMA
PRESCOTT
WINSLOW
ZUNI
FARMINGTON
ALBUQUERQUE
TUCUMCARI
CLAYTON
GOODLAND
RUSSELL
DODGE CITY
WICHITA
KANSAS CITY
COLUMBIA
ST LOUIS
SPRINGFIELD
INDIANAPOLIS
EVANSVILLE
COLUMBUS
CINCINNATI
LEXINGTON
PHOENIX
TRUTH or CONSEQUENCES
ROSWELL
TUCSON
EL PASO
AMARILLO
LUBBOCK
OKLAHOMA CITY
TULSA
WICHITA FALLS
FORT SMITH
LITTLE ROCK
ABILENE
FORT WORTH
MIDLAND
WACO
SHREVEPORT
LUFKIN
JUNCTION
DEL RIO
SAN ANTONIO
HOUSTON
LAKE CHARLES
NEW ORLEANS
LAREDO
CORPUS CHRISTI
BROWNSVILLE
MEMPHIS
NASHVILLE
KNOXVILLE
CHATTANOOGA
BIRMINGHAM
MERIDIAN
MONTGOMERY
ATLANTA
MACON
AUGUSTA
COLUMBIA
MOBILE
TALLAHASSEE
JACKSONVILLE
DAYTONA BEACH
TAMPA
MIAMI
KEY WEST
CHARLOTTE
RALEIGH
WILMINGTON
CHARLESTON
CAPE HATTERAS
NORFOLK
RICHMOND
ROANOKE
CHARLESTON
ELKINS
WASHINGTON
PITTSBURGH
BRADFORD
HARRISBURG
WILLIAMSPORT
PHILADELPHIA
NEW YORK
HARTFORD
BUFFALO
SYRACUSE
ALBANY
MASSENA
BURLINGTON
CONCORD
PORTLAND
BOSTON
NANTUCKET
OLD TOWN
CARIBOU
SAN JUAN
GULF OF MEXICO

Fig. 1 Primary weather reporting network



LOCAL CLIMATOLOGICAL DATA
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

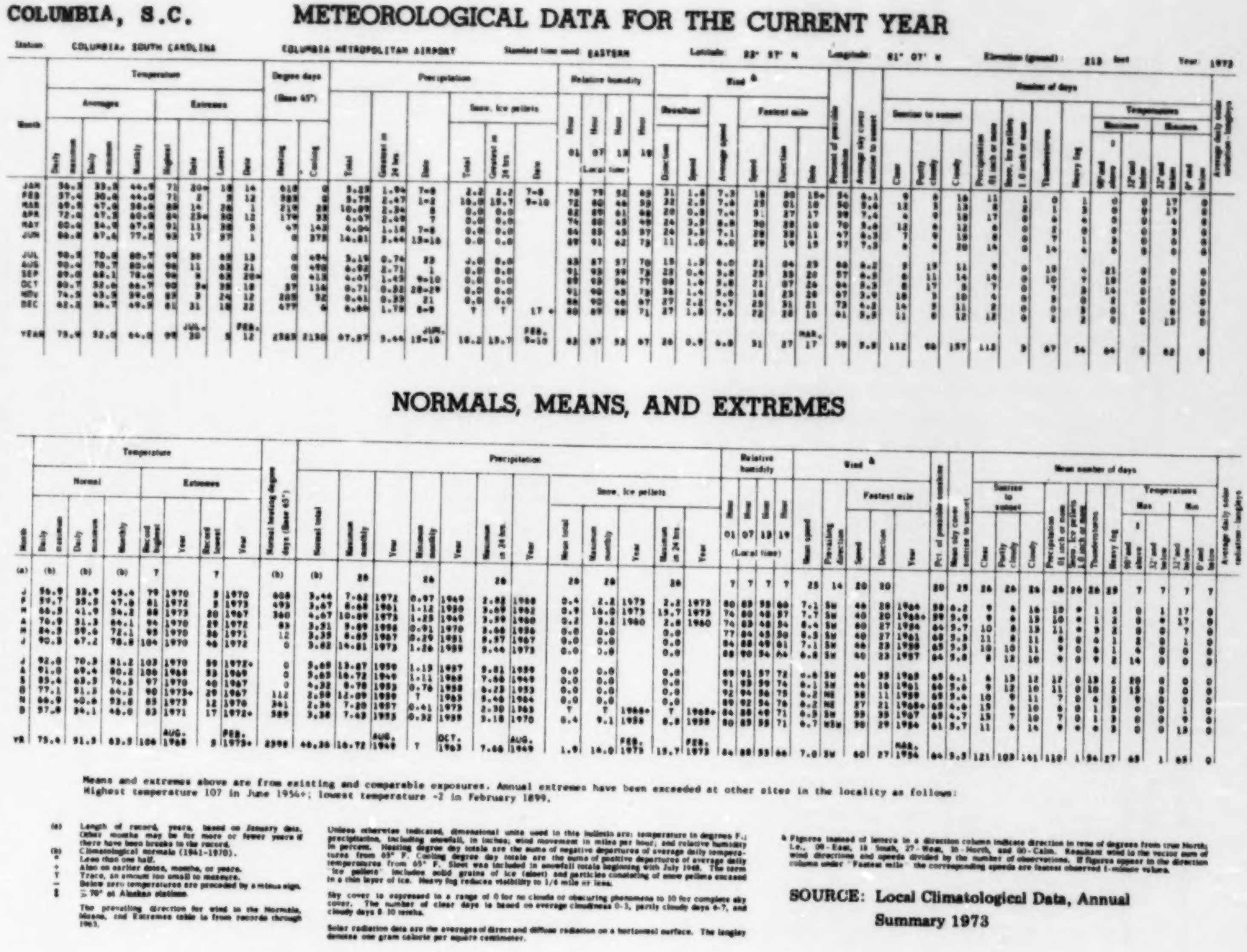
Subscription Price: Local Climatological Data $1.00 per year including annual summary if published. Single copy: 10 cents for monthly summary; 15 cents for annual summary. Checks or money orders should be made payable and remittances and correspondence should be sent to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

William H. Haggard

Director, National Climatic Center

Fig. 2 Local climatological data (monthly) prepared for stations in the primary network



COLUMBIA, S.C.

METEOROLOGICAL DATA FOR THE CURRENT YEAR

Station: COLUMBIA, SOUTH CAROLINA COLUMBIA METROPOLITAN AIRPORT Standard time used: EASTERN Latitude: 33° 57' N Longitude: 81° 07' W Elevation (ground): 213 feet Year: 1973

NORMALS, MEANS, AND EXTREMES

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 107 in June 1954+; lowest temperature -2 in February 1899.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological normals (1941-1970).
* Less than one half.
+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
— Below zero temperatures are preceded by a minus sign.
‡ ≥ 70° at Alaskan stations.

The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

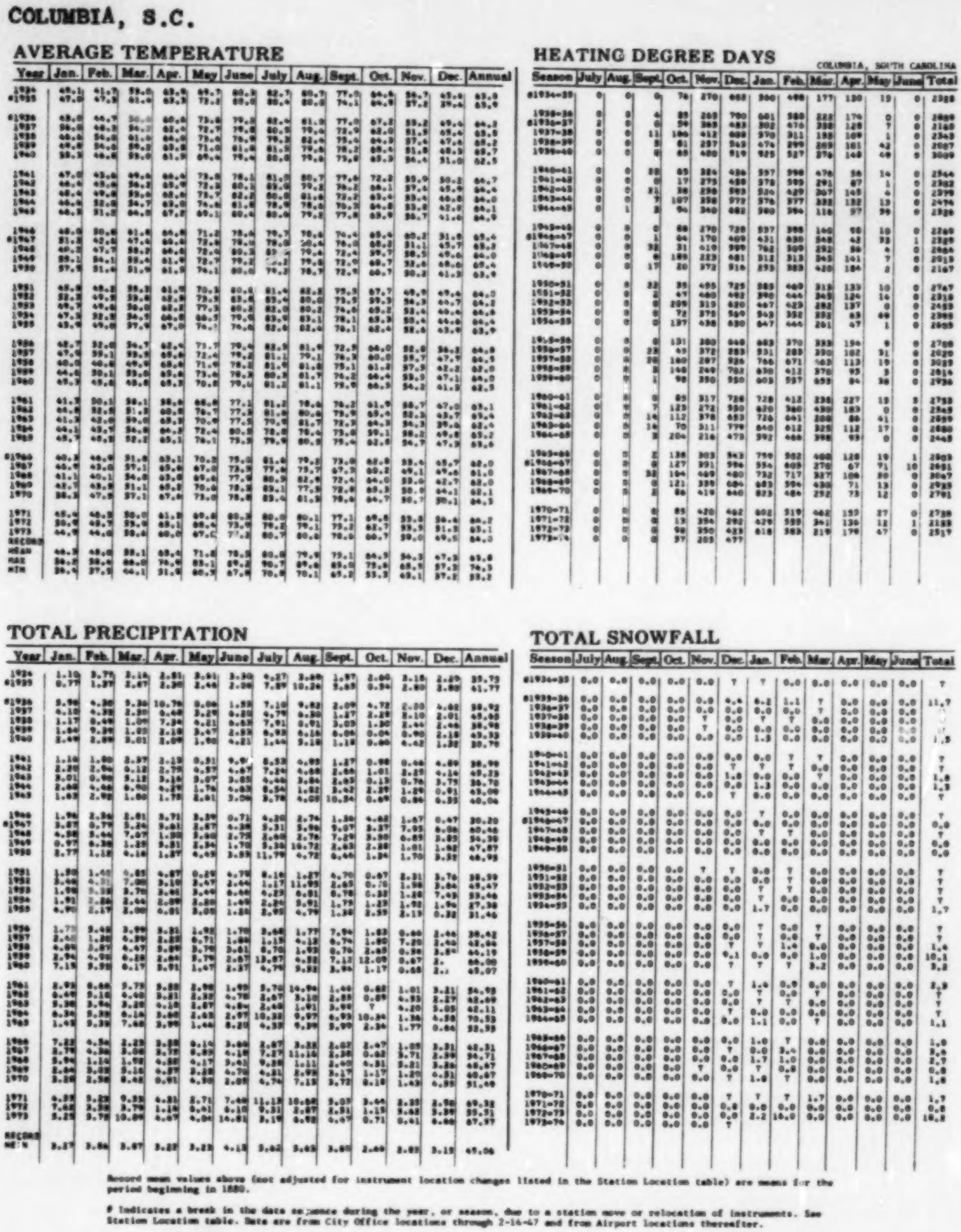
Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

SOURCE: Local Climatological Data, Annual Summary 1973

Fig. 3 Local climatological data (annual) prepared for stations in the primary network

B



COLUMBIA, S.C.

AVERAGE TEMPERATURE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual

HEATING DEGREE DAYS

COLUMBIA, SOUTH CAROLINA

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total

TOTAL PRECIPITATION

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual

TOTAL SNOWFALL

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total

Record mean values above (not adjusted for instrument location changes listed in the Station Location table) are means for the period beginning in 1880.

# Indicates a break in the data sequence during the year, or season, due to a station move or relocation of instruments. See Station Location table. Data are from City Office locations through 2-16-47 and from Airport locations thereafter.

Fig. 4 Sequential tables in the local climatological data (annual)

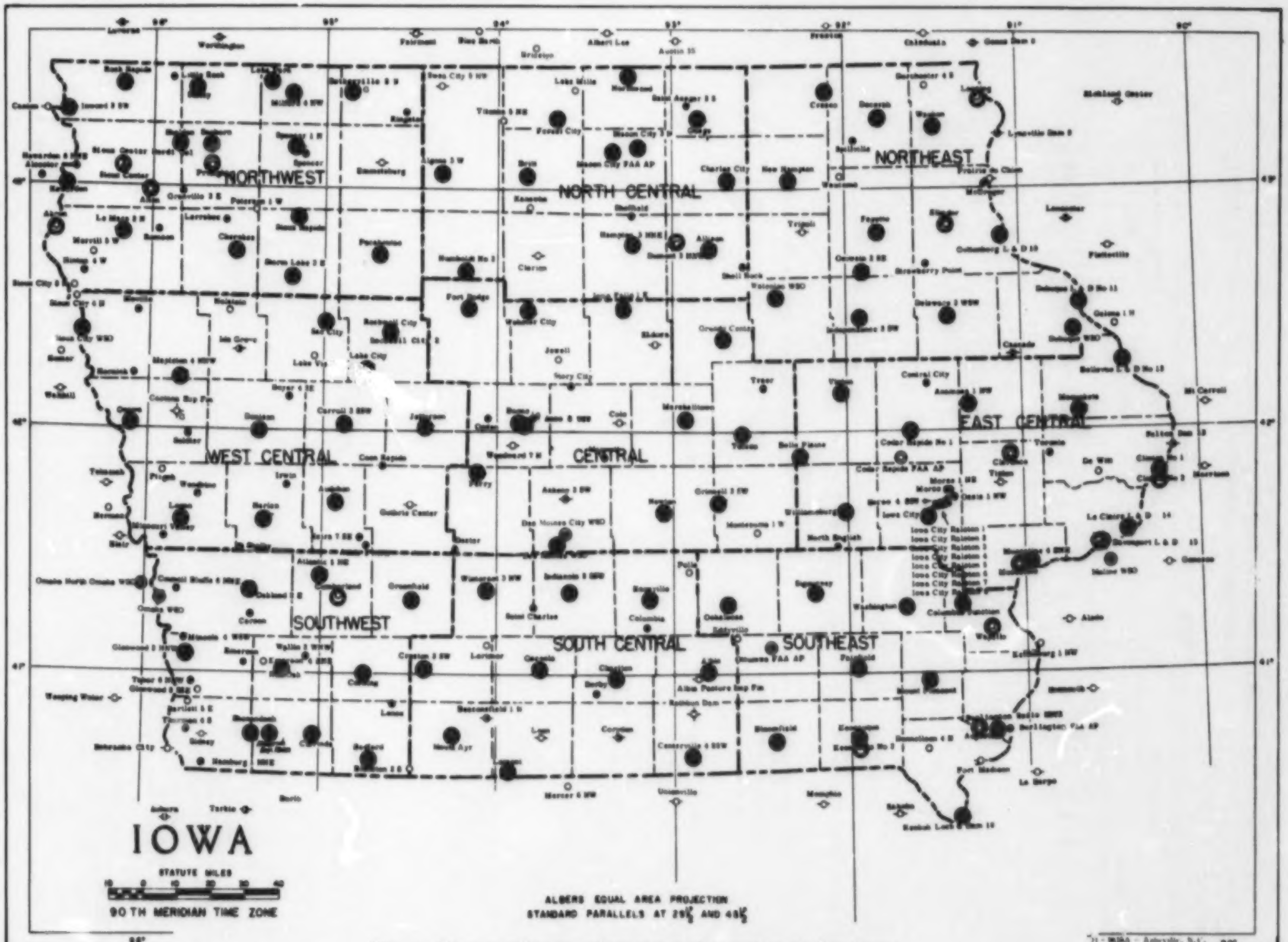
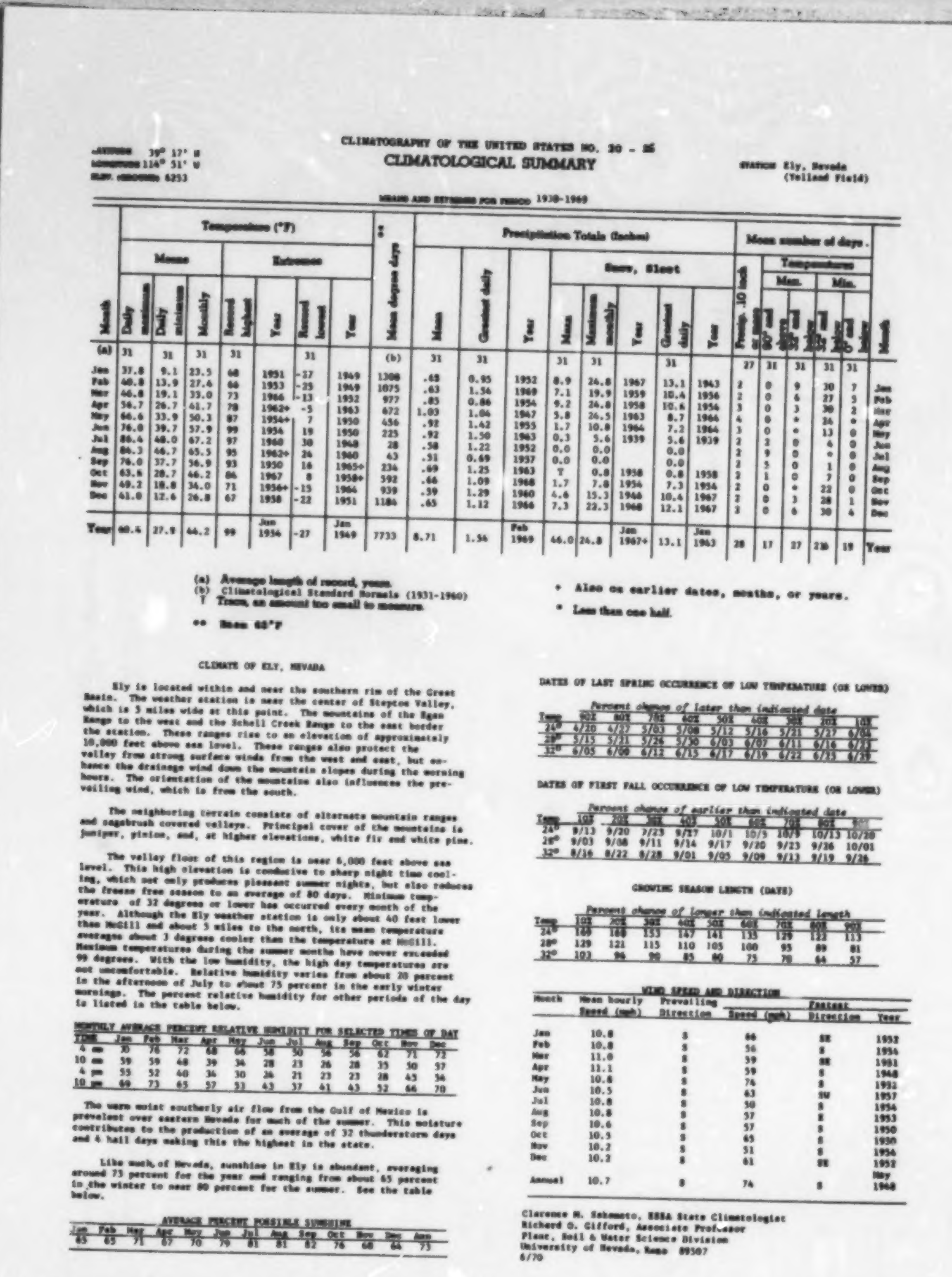

NORTHWEST
NORTH CENTRAL
NORTHEAST
WEST CENTRAL
CENTRAL
EAST CENTRAL
SOUTHWEST
SOUTH CENTRAL
SOUTHEAST
IOWA
STATUTE MILES
10 0 10 20 30 40
90TH MERIDIAN TIME ZONE
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS AT 29½ AND 45½
96°
95°
94°
93°
92°
91°
90°
43°
42°
41°
Fort Dodge
Charles City
Cedar Rapids FAA AP
Des Moines City WSO
Iowa City
Burlington FAA AP
Ottumwa FAA AP
Sioux City WSO

Fig. 1 Cooperative weather reporting network for Iowa

C



LATITUDE 39° 17' N
LONGITUDE 114° 51' W
ELEV. (GROUND) 6253

CLIMATOGRAPHY OF THE UNITED STATES NO. 20 - 26

CLIMATOLOGICAL SUMMARY

STATION Ely, Nevada
(Yelland Field)

MEANS AND EXTREMES FOR PERIOD 1938-1969

Month	Temperature (°F) Means Daily maximum	Daily minimum	Monthly	Extremes Record highest	Year	Record lowest	Year	Mean degree days **	Precipitation Totals (Inches) Mean	Greatest daily	Year	Snow, Sleet Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days Precip. .10 inch or more	Temperatures Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Month
(a)	31	31	31	31		31		(b)	31	31		31	31		31		27	31	31	31	31	
Jan	37.8	9.1	23.5	68	1951	-27	1949	1308	.68	0.95	1952	8.9	24.8	1967	13.1	1943	2	0	9	30	7	Jan
Feb	40.8	13.9	27.4	66	1953	-25	1949	1075	.63	1.56	1969	7.1	19.9	1959	10.4	1956	2	0	6	27	5	Feb
Mar	46.8	19.1	33.0	73	1966	-13	1952	977	.85	0.86	1954	9.2	24.8	1958	10.6	1956	3	0	3	30	2	Mar
Apr	56.7	26.7	41.7	78	1962+	-5	1963	672	1.03	1.06	1967	5.8	24.5	1963	8.7	1966	4	0	*	26	*	Apr
May	66.6	33.9	50.3	87	1954+	7	1950	456	.92	1.42	1955	1.7	10.8	1964	7.2	1964	3	0	*	13	0	May
Jun	76.0	39.7	57.9	99	1956	19	1950	225	.92	1.50	1963	0.3	5.6	1939	5.6	1939	2	2	0	4	0	Jun
Jul	86.4	48.0	67.2	97	1960	30	1968	28	.58	1.22	1952	0.0	0.0		0.0		2	9	0	*	0	Jul
Aug	84.3	46.7	65.5	95	1962+	24	1960	43	.51	0.69	1957	0.0	0.0		0.0		2	5	0	1	0	Aug
Sep	76.0	37.7	56.9	93	1950	16	1965+	234	.69	1.25	1963	T	0.8	1958	0.8	1958	2	1	0	7	0	Sep
Oct	63.6	28.7	46.2	86	1967	8	1958+	592	.66	1.09	1968	1.7	7.8	1954	7.3	1954	2	0	*	22	0	Oct
Nov	49.2	18.8	34.0	71	1956+	-15	1964	939	.39	1.29	1960	4.6	15.3	1966	10.4	1967	2	0	3	28	1	Nov
Dec	41.0	12.6	26.8	67	1958	-22	1951	1184	.65	1.12	1966	7.3	22.3	1968	12.1	1967	2	0	6	30	4	Dec
Year	60.4	27.9	44.2	99	Jun 1956	-27	Jan 1949	7733	8.71	1.56	Feb 1969	46.0	24.8	Jan 1967+	13.1	Jan 1943	28	17	27	218	19	Year

(a) Average length of record, years.
(b) Climatological Standard Normals (1931-1960)
T Trace, an amount too small to measure.

** Base 65°F

+ Also on earlier dates, months, or years.

* Less than one half.

CLIMATE OF ELY, NEVADA

Ely is located within and near the southern rim of the Great Basin. The weather station is near the center of Steptoe Valley, which is 3 miles wide at this point. The mountains of the Egan Range to the west and the Schell Creek Range to the east border the station. These ranges rise to an elevation of approximately 10,000 feet above sea level. These ranges also protect the valley from strong surface winds from the west and east, but enhance the drainage wind down the mountain slopes during the morning hours. The orientation of the mountains also influences the prevailing wind, which is from the south.

The neighboring terrain consists of alternate mountain ranges and sagebrush covered valleys. Principal cover of the mountains is juniper, pinion, and, at higher elevations, white fir and white pine.

The valley floor of this region is near 6,000 feet above sea level. This high elevation is conducive to sharp night time cooling, which not only produces pleasant summer nights, but also reduces the freeze free season to an average of 80 days. Minimum temperature of 32 degrees or lower has occurred every month of the year. Although the Ely weather station is only about 40 feet lower than McGill and about 3 miles to the north, its mean temperature averages about 3 degrees cooler than the temperature at McGill. Maximum temperatures during the summer months have never exceeded 99 degrees. With the low humidity, the high day temperatures are not uncomfortable. Relative humidity varies from about 20 percent in the afternoon of July to about 75 percent in the early winter mornings. The percent relative humidity for other periods of the day is listed in the table below.

MONTHLY AVERAGE PERCENT RELATIVE HUMIDITY FOR SELECTED TIMES OF DAY

TIME	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4 am	70	76	72	68	66	58	50	56	56	62	71	72
10 am	59	59	48	39	34	28	23	26	28	35	50	57
4 pm	55	52	40	36	30	26	21	23	23	28	45	56
10 pm	69	73	65	57	53	43	37	41	43	52	66	70

The warm moist southerly air flow from the Gulf of Mexico is prevalent over eastern Nevada for much of the summer. This moisture contributes to the production of an average of 32 thunderstorm days and 4 hail days making this the highest in the state.

Like much of Nevada, sunshine in Ely is abundant, averaging around 73 percent for the year and ranging from about 65 percent in the winter to near 80 percent for the summer. See the table below.

AVERAGE PERCENT POSSIBLE SUNSHINE

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
65	65	71	67	70	79	81	81	82	76	68	64	73

DATES OF LAST SPRING OCCURRENCE OF LOW TEMPERATURE (OR LOWER)

Temp	Percent chance of later than indicated date 90%	80%	70%	60%	50%	40%	30%	20%	10%
24°	4/20	4/27	5/03	5/08	5/12	5/16	5/21	5/27	6/04
28°	5/15	5/21	5/26	5/30	6/03	6/07	6/11	6/16	6/23
32°	6/05	6/08	6/12	6/15	6/17	6/19	6/22	6/25	6/29

DATES OF FIRST FALL OCCURRENCE OF LOW TEMPERATURE (OR LOWER)

Temp	Percent chance of earlier than indicated date 10%	20%	30%	40%	50%	60%	70%	80%	90%
24°	9/13	9/20	9/23	9/27	10/1	10/5	10/9	10/13	10/20
28°	9/03	9/08	9/11	9/14	9/17	9/20	9/23	9/26	10/01
32°	8/16	8/22	8/28	9/01	9/05	9/09	9/13	9/19	9/26

GROWING SEASON LENGTH (DAYS)

Temp	Percent chance of longer than indicated length 10%	20%	30%	40%	50%	60%	70%	80%	90%
24°	169	160	153	147	141	135	129	122	113
28°	129	121	115	110	105	100	95	89	81
32°	103	96	90	85	80	75	70	64	57

WIND SPEED AND DIRECTION

Month	Mean hourly Speed (mph)	Prevailing Direction	Fastest Speed (mph)	Fastest Direction	Year
Jan	10.8	S	66	SE	1952
Feb	10.8	S	56	S	1956
Mar	11.0	S	59	SE	1951
Apr	11.1	S	59	S	1948
May	10.8	S	74	S	1952
Jun	10.5	S	63	SW	1957
Jul	10.8	S	50	S	1954
Aug	10.8	S	57	S	1953
Sep	10.6	S	57	S	1950
Oct	10.5	S	65	S	1950
Nov	10.2	S	51	S	1956
Dec	10.2	S	61	SE	1952
Annual	10.7	S	74	S	May 1948

Clarence M. Sakamoto, ESSA State Climatologist
Richard O. Gifford, Associate Professor
Plant, Soil & Water Science Division
University of Nevada, Reno 89507
6/70

Fig. 2 Climatography of the United States No.20 prepared for stations in the cooperative network

Average Temperature (°F)

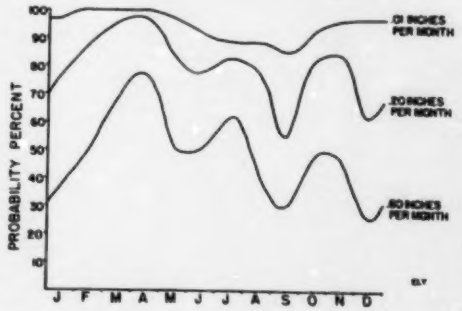
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1938										44.8	28.6	27.3	
1939	21.1	14.7	34.5	45.8	51.8	57.4	67.4	66.3	57.1	44.4	37.7	34.0	44.4
1940	26.4	31.2	38.3	43.4	55.4	62.6	68.1	68.1	56.3	47.1	31.9	30.4	46.6
1941	27.2	34.7	36.2	36.2	51.4	55.8	65.1	63.0	51.1	41.8	34.6	28.6	43.8
1942	23.4	23.8	30.6	41.6	46.0	57.4	70.1	65.6	55.7	45.6	35.0	31.2	43.8
1943	25.3	28.8	36.8	48.1	49.8	54.6	66.6	65.8	59.3	46.8	36.2	27.1	45.4
1944	18.7	23.0	29.5	38.0	51.0	53.4	65.2	63.8	57.0	47.4	30.4	25.5	41.9
1945	25.6	29.0	27.6	37.4	49.0	53.4	67.2	65.3	55.0	48.0	32.6	24.6	42.9
1946	21.2	25.8	35.4	45.2	48.3	59.8	67.6	66.5	56.2	39.8	29.8	30.0	43.8
1947	20.0	34.8	37.6	41.2	53.5	55.8	67.3	65.5	58.4	48.3	29.0	24.8	44.7
1948	28.8	24.0	26.4	42.8	48.8	57.4	66.2	64.5	57.1	44.9	30.4	18.9	42.5
1949	5.8	15.0	31.8	46.0	50.0	57.6	66.3	64.5	59.0	43.0	41.4	23.4	42.0
1950	20.2	33.0	33.7	42.4	47.3	56.7	65.9	63.8	54.8	51.1	39.0	34.8	45.2
1951	25.3	29.3	32.3	43.5	50.3	56.8	67.3	64.8	57.6	43.0	31.8	18.4	43.4
1952	17.6	19.9	22.4	43.0	52.1	57.3	66.5	67.5	59.3	50.6	26.9	24.6	42.3
1953	33.5	30.7	35.1	39.8	42.7	57.5	69.1	65.2	59.7	45.9	37.9	24.1	45.1
1954	27.2	34.3	31.8	46.1	54.0	57.7	69.6	64.0	56.5	46.0	38.8	25.8	46.0
1955	14.6	17.9	31.4	39.3	47.8	57.6	65.2	67.7	56.8	47.3	31.6	28.6	42.2
1956	31.9	19.5	35.8	41.3	50.5	60.5	65.6	62.9	59.8	44.2	30.6	26.8	44.1
1957	18.7	34.3	35.9	41.0	47.5	60.0	67.0	66.5	56.4	43.5	29.1	30.6	44.2
1958	27.5	33.9	30.2	38.2	54.1	59.5	65.7	68.6	57.8	47.5	34.6	33.9	46.0
1959	28.8	26.0	35.6	44.8	47.4	63.3	69.4	65.5	53.5	46.1	34.4	25.9	45.0
1960	19.0	23.3	39.3	43.2	50.3	62.6	68.0	65.4	60.6	46.3	35.3	26.6	45.0
1961	27.0	31.7	34.0	41.4	50.2	62.4	68.4	66.1	52.6	43.4	30.5	25.1	44.4
1962	20.4	29.4	29.3	47.4	49.0	59.6	65.5	65.8	58.9	48.7	38.0	29.7	45.2
1963	22.9	36.8	32.3	36.1	54.3	53.7	66.5	65.3	59.8	50.7	43.3	27.6	45.0
1964	19.3	22.3	27.9	39.6	48.6	56.6	68.4	64.7	54.4	49.6	29.3	26.0	42.2
1965	29.4	27.8	32.4	41.9	45.9	55.2	65.5	63.6	50.5	49.2	37.6	24.5	43.6
1966	20.1	22.5	36.7	42.6	55.5	60.6	68.6	66.3	59.1	45.7	38.1	27.0	45.2
1967	26.2	28.4	38.4	34.7	49.2	54.6	68.1	68.1	57.9	47.7	37.6	17.6	44.1
1968	23.1	35.8	36.7	38.0	49.3	59.4	68.4	61.1	54.5	46.7	34.8	23.8	44.3
1969	31.2	25.9	26.2	43.2	56.9	57.4	68.5	69.6	60.7	40.4	35.1	29.8	45.4

STATION HISTORY

The first observation at the Ely weather station was taken on October 12, 1938. Original instrumentation consisted of wind instruments, thermometers, psychrometer, tipping bucket rain gage, weighing rain gage, 8-inch rain gage, and a pyronometer, located at 6262 feet. The equipment has been located at Yelland Field since 1938, with only one minor change. On September 8, 1961, the entire station was moved to the Yelland Field FAA - Weather Bureau Building, some 400 feet north northwest of the previous location. Area conditions were the same so that there was no change in exposure or elevation. All records are considered compatible. During the changeover, the wind equipment was moved 3,000 feet further north to the center of the airfield, and lowered from 46 feet to 20 feet above the ground. Also, the pyronometer was raised in elevation from 6262 feet to 6279 feet above mean sea level.

Total Precipitation (Inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1938											0.42	0.43	
1939	0.83	0.56	0.87	1.57	0.60	0.94	1.42	0.53	1.47	1.69	0.07	0.07	10.62
1940	0.95	1.12	0.51	1.76	0.07	0.70	0.03	0.05	2.07	1.06	0.19	0.15	8.66
1941	0.35	0.60	0.93	2.63	1.84	1.45	1.35	0.75	0.19	1.76	0.67	0.80	13.52
1942	0.63	0.27	1.03	0.59	0.69	T	0.15	0.17	T	0.40	0.61	0.06	4.60
1943	1.00	0.50	0.44	1.58	0.11	1.10	0.17	0.27	0.35	1.35	0.29	0.91	8.27
1944	0.53	0.56	0.99	1.16	0.52	1.15	T	T	0.11	0.43	1.60	0.44	7.49
1945	0.23	0.63	2.01	1.31	1.04	2.39	0.43	1.58	1.03	1.48	0.87	[illegible]	13.23
1946	0.62	0.08	1.22	0.97	1.21	T	1.18	0.54	0.01	1.46	1.60	0.67	9.56
1947	0.14	0.28	0.21	1.79	1.17	0.49	T	0.48	1.06	0.81	0.20	0.30	6.91
1948	T	0.89	0.87	0.62	T	0.92	T	0.26	0.26	0.47	0.10	0.92	5.31
1949	0.78	0.48	0.53	0.36	1.53	0.57	0.63	0.18	0.36	0.61	0.42	0.43	6.88
1950	0.45	0.13	0.88	0.16	0.87	0.04	0.87	0.06	0.98	0.63	0.54	0.42	6.03
1951	0.13	0.08	0.20	0.94	0.48	0.36	1.33	1.05	0.10	0.32	0.76	1.54	7.29
1952	1.92	0.87	2.40	1.77	0.36	0.51	1.51	0.19	0.03	0.00	0.43	0.99	10.98
1953	0.51	0.14	0.32	0.45	0.49	0.33	1.13	0.74	T	0.57	0.10	0.24	5.22
1954	0.94	0.54	1.37	0.54	0.28	0.19	0.32	0.05	1.48	0.47	1.12	0.59	7.89
1955	1.00	0.76	0.07	0.21	1.74	0.76	0.47	1.21	0.16	0.04	0.66	1.60	8.76
1956	0.99	0.94	0.36	0.63	1.61	0.38	0.18	T	0.65	0.54	0.04	0.06	6.36
1957	1.01	0.17	1.14	0.53	2.68	0.41	0.66	0.71	0.02	0.77	0.54	0.50	9.14
1958	0.53	1.08	2.25	0.69	0.58	0.35	0.12	0.49	0.79	T	0.53	0.17	7.58
1959	0.17	1.43	0.31	0.46	1.07	0.17	0.16	0.44	0.99	0.15	T	0.62	5.97
1960	0.80	0.70	.077	0.67	0.79	0.21	0.26	0.19	0.98	0.37	1.82	0.33	7.89
1961	0.15	0.36	1.21	0.80	0.64	0.56	0.64	1.14	0.41	0.32	0.36	0.48	7.27
1962	0.81	1.51	1.09	0.18	1.26	0.45	0.67	T	0.10	1.06	0.28	T	7.36
1963	0.11	0.49	0.84	2.12	0.40	3.53	0.01	0.29	2.18	0.37	0.60	0.20	11.14
1964	1.41	0.07	1.24	2.77	1.17	2.46	0.02	0.58	0.09	0.19	0.93	1.79	12.70
1965	0.46	0.64	0.46	0.74	0.54	1.25	1.12	1.52	1.56	0.27	0.93	1.28	10.77
1966	0.23	0.31	0.16	0.16	0.46	0.14	0.16	0.61	1.34	0.10	0.30	2.11	6.08
1967	1.86	0.10	0.37	1.38	3.05	2.83	0.84	0.41	2.23	0.13	0.84	0.69	14.73
1968	0.15	0.92	0.67	1.26	1.00	1.12	1.32	1.04	0.10	1.44	0.22	0.79	10.03
1969	1.24	2.19	0.41	0.98	0.28	2.80	0.55	0.34	0.37	0.91	0.79	0.59	11.45



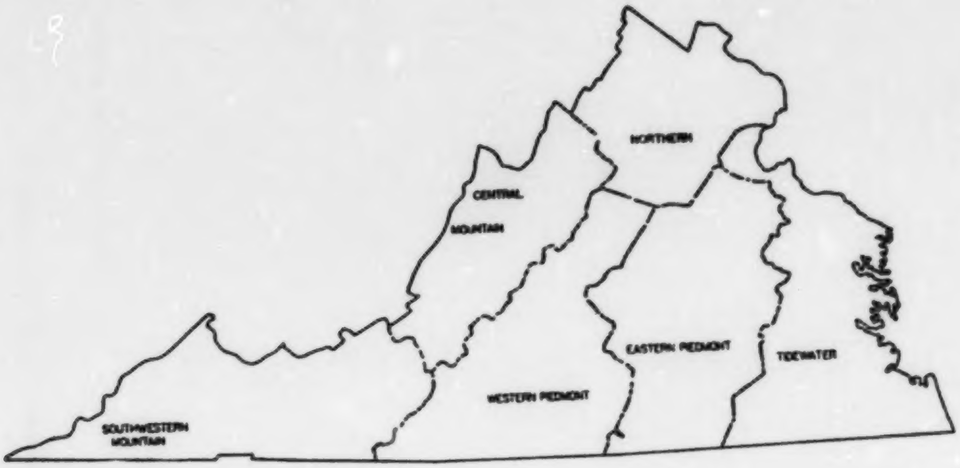
PRECIPITATION PROBABILITY

The figure on the left represents the chance (percent probability of receiving at least the indicated amount (inch) of precipitation (liquid form) per month. To use the figure, determine your critical amount: 0.01, 0.20, or 0.60 inch per month. Locate the time period on the bottom scale; proceed up until the amount is intersected. Find the chance of receiving at least this amount on the left scale. For example, the chance of at least 0.20 inch per month in the middle of September is approximately 55 percent (the mid-month value is utilized).

Fig. 3 Climatography of the United States No. 20, page 2

C

VIRGINIA


NORTHERN
CENTRAL
MOUNTAIN
EASTERN PIEDMONT
TIDEWATER
WESTERN PIEDMONT
SOUTHWESTERN
MOUNTAIN

For hydrology, agriculture uses, energy supply, etc. it is sometimes necessary to use values averaged over an area of a state rather than a point (station). Each state is divided into divisions (up to 10) which represent, as nearly as possible, homogeneous climatic regimes. These divisions have been established to provide assistance to a variety of interests, and some areas (Rocky Mountain States, for example) may have rather extreme variations within a division. The data presented have many applications, but like all climatological products they must be used within the framework for which they were designed.

Fig. 1 Climatological divisions in Virginia

MONTHLY AVERAGES OF TEMPERATURE AND PRECIPITATION FOR STATE CLIMATIC DIVISIONS 1941-70

MONTHLY AND ANNUAL DIVISIONAL AVERAGES
TEMPERATURE (°F)

DIVISIONS **VIRGINIA**

TIDEWATER 01	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1941	37.8	35.8	41.7	58.7	68.3	75.2	78.0	76.4	73.4	60.6	51.7	44.2	58.8
1942	38.8	36.9	48.7	58.4	69.1	75.5	79.8	75.6	72.1	61.5	52.0	38.4	58.7
1943	40.6	42.0	47.0	53.6	68.3	78.8	77.9	77.1	68.7	58.2	48.8	39.0	58.5
1944	39.3	40.9	45.6	55.9	70.8	76.1	77.7	75.6	72.0	59.5	48.7	37.1	58.6
1945	39.2	41.2	57.2	60.5	66.0	75.2	76.7	75.0	74.6	59.6	52.4	35.4	58.9
1946	40.0	42.9	54.6	57.0	66.1	72.7	75.5	73.2	70.5	62.0	54.3	44.9	59.5
1947	45.3	34.7	40.4	57.7	67.4	72.5	75.8	78.2	72.0	64.8	48.0	39.0	58.0
1948	32.8	40.5	51.4	57.4	66.3	74.3	78.4	76.2	70.3	57.6	55.4	44.0	58.7
1949	47.2	47.7	48.9	57.0	66.0	75.0	80.9	77.6	69.2	64.5	50.0	44.1	60.7
1950	51.0	42.6	45.9	54.6	64.8	73.8	77.0	75.1	69.8	62.1	49.3	37.5	58.6
1951	42.9	42.3	47.2	56.9	65.0	74.2	78.3	76.7	71.0	62.9	47.5	44.2	59.1
1952	43.9	42.7	47.2	59.1	66.2	78.0	80.2	77.1	70.8	56.7	50.8	41.1	59.5
1953	44.7	45.2	49.4	58.0	71.3	74.6	79.7	77.1	71.0	61.7	49.9	44.1	60.5
1954	40.1	46.2	48.7	61.3	63.9	74.9	77.8	77.3	73.8	63.8	47.6	39.6	59.6
1955	37.1	40.3	51.8	60.5	67.4	70.9	81.1	79.5	71.6	61.3	49.0	36.3	58.9
1956	36.7	44.5	47.3	55.7	65.0	74.7	77.8	76.5	69.6	62.3	50.1	50.2	59.2
1957	37.6	45.9	47.7	61.6	68.1	76.6	78.1	75.2	73.4	56.5	52.0	44.8	59.6
1958	35.6	35.0	45.1	57.3	66.1	71.4	80.5	76.9	69.6	60.0	53.4	35.0	57.0
1959	38.2	42.1	48.2	59.6	69.3	75.2	78.0	79.3	72.4	63.5	50.2	43.7	60.0
1960	40.9	40.9	37.2	61.8	65.3	74.3	76.5	78.6	71.5	60.6	51.4	35.5	57.9
1961	34.0	42.7	50.9	53.8	63.1	72.3	78.8	77.3	74.4	60.3	52.5	40.3	58.4
1962	38.4	39.9	44.8	57.0	68.9	73.3	75.1	75.6	68.4	61.9	48.0	36.6	57.3
1963	35.7	34.3	51.4	58.4	63.9	75.0	77.0	76.1	67.0	60.8	52.1	34.7	57.0
1964	40.4	39.2	49.3	55.7	66.7	74.3	77.1	74.5	70.3	56.5	53.4	44.7	58.5
1965	38.4	39.8	43.9	56.1	69.4	71.8	76.4	76.7	72.6	58.5	50.8	42.9	57.9
1966	34.9	38.1	48.0	56.2	64.2	72.4	78.4	76.1	69.5	58.7	50.0	40.2	57.1
1967	42.9	37.9	47.0	58.3	60.9	71.0	75.8	74.9	66.5	58.8	46.0	43.3	56.9
1968	34.8	34.5	49.7	58.3	64.1	74.3	78.0	78.9	70.2	62.1	52.3	39.1	57.0
1969	36.4	38.3	43.2	58.5	65.8	75.7	78.3	75.2	69.7	60.5	48.5	39.2	57.4
1970	32.5	39.8	44.0	56.2	67.8	74.5	76.9	77.4	74.2	63.1	51.1	42.6	58.3
NORMAL	39.1	40.4	47.4	57.5	66.5	74.1	77.9	76.6	71.0	60.9	50.6	40.7	58.6

EASTERN PIEDMONT 02	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1941	36.5	35.1	41.5	59.8	67.0	73.0	78.5	76.0	72.3	65.3	49.5	42.5	58.1
1942	36.5	36.1	48.7	58.9	68.6	75.2	78.5	74.9	70.2	59.6	49.5	36.6	57.7
1943	40.0	41.0	46.8	53.8	68.6	78.3	77.7	77.5	66.8	56.3	46.3	38.1	57.6

MONTHLY AND ANNUAL DIVISIONAL AVERAGES
PRECIPITATION (INCHES)

DIVISIONS **VIRGINIA**

TIDEWATER 01	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1941	2.49	1.89	3.24	3.10	1.35	3.64	5.53	2.99	0.89	1.18	0.89	2.95	29.14
1942	2.90	1.64	3.49	0.65	1.79	3.38	4.69	8.67	4.57	6.28	1.12	3.36	44.54
1943	2.60	2.50	3.47	2.53	4.29	3.65	4.51	1.79	3.72	4.37	1.78	1.76	36.71
1944	3.76	4.91	3.98	3.55	1.17	1.74	4.31	4.31	5.93	2.79	3.78	2.24	44.67
1945	2.40	4.01	1.15	2.90	3.77	5.21	13.10	3.04	5.39	1.87	3.26	6.11	52.21
1946	2.43	2.91	2.28	3.08	6.98	4.08	4.55	5.20	3.32	2.41	2.37	1.75	41.36
1947	4.39	1.39	2.39	2.47	2.79	4.31	3.83	2.39	4.93	2.08	5.21	1.89	38.05
1948	3.96	2.90	3.30	4.59	6.55	3.57	3.97	6.73	3.06	2.83	6.37	4.72	52.53
1949	2.47	3.74	2.43	2.13	4.89	3.47	5.49	8.01	3.16	2.43	2.98	1.93	43.11
1950	2.24	1.59	3.25	1.87	3.52	2.11	7.84	4.23	4.30	1.83	1.78	2.48	37.20
1951	1.60	1.94	3.18	2.77	2.60	5.36	3.87	4.71	1.47	2.74	5.37	3.42	39.03
1952	5.41	4.00	4.68	3.55	3.06	2.33	3.52	5.24	2.55	2.22	5.20	3.18	44.96
1953	2.65	3.17	3.73	3.80	3.55	3.61	2.34	6.52	4.12	1.31	2.47	3.06	40.31
1954	4.86	1.79	3.73	2.00	5.08	1.19	4.12	4.24	2.07	2.54	2.04	3.01	37.29
1955	1.58	3.22	3.70	2.59	2.20	4.39	3.79	10.77	6.55	2.30	2.12	1.37	44.78
1956	2.24	4.40	3.15	3.26	3.01	2.76	7.67	3.98	4.11	6.29	2.56	3.29	46.52
1957	3.60	4.65	4.44	2.36	2.23	3.73	2.07	6.13	4.76	4.82	5.15	5.37	49.31
1958	5.71	3.71	5.77	4.26	5.90	5.11	4.49	9.46	0.94	4.30	2.17	3.86	53.86
1959	1.68	1.95	3.50	4.77	1.82	2.26	8.69	2.32	3.30	6.52	3.55	2.57	42.91
1960	2.96	4.19	2.85	2.48	5.71	3.08	6.67	6.11	7.20	3.58	1.12	2.39	48.34
1961	3.39	5.21	4.24	2.63	6.29	5.66	2.93	4.43	2.28	3.71	1.67	4.86	49.30
1962	3.16	3.34	4.18	4.16	2.65	5.37	5.39	3.26	3.80	2.08	5.76	3.14	48.27
1963	2.83	3.03	4.74	0.83	2.81	7.62	1.69	2.46	4.75	0.48	5.32	2.69	39.25
1964	4.11	4.89	2.60	3.34	1.55	4.98	4.40	5.08	6.74	4.72	1.74	2.48	45.63
1965	2.38	2.10	3.55	2.42	1.09	4.55	6.40	2.36	2.06	1.18	0.42	0.65	29.32
1966	4.27	3.65	1.62	2.04	4.58	3.63	3.36	3.85	4.78	2.30	1.04	3.03	38.19
1967	2.81	3.55	2.12	1.29	3.52	2.08	4.63	7.03	2.14	1.10	1.76	3.39	38.20
1968	2.83	0.97	4.32	2.40	3.15	3.72	4.40	3.01	1.90	2.82	3.48	2.61	35.63
1969	2.63	3.09	4.20	2.60	2.26	3.52	6.81	6.97	3.25	1.82	2.75	3.08	44.44
1970	2.09	3.24	4.04	3.51	2.23	3.27	5.83	2.48	2.17	1.03	3.49	2.78	38.69
NORMAL	3.08	3.12	3.56	2.82	3.41	3.70	5.02	4.99	3.68	2.97	2.86	3.15	42.38

EASTERN PIEDMONT 02	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1941	2.45	1.20	2.44	3.64	1.03	4.87	6.84	2.38	1.55	0.61	0.68	3.20	30.99
1942	3.24	1.66	4.65	0.68	2.71	4.64	5.87	8.05	4.16	6.13	1.73	3.09	47.19
1943	3.31	2.00	4.08	2.38	3.30	3.93	4.86	1.20	3.21	1.36	2.61	2.46	35.10
1944	2.61	4.82	6.30	3.80	2.24	1.61	5.34	4.34	6.56	2.44	2.98	2.38	47.68
1945	2.62	3.39	1.31	3.27	5.00	1.96	11.92	2.71	7.53	1.30	3.01	3.59	49.59
1946	2.51	2.94	3.12	3.18	6.07	3.55	5.98	3.06	3.57	2.44	1.50	2.34	41.20
1947	4.60	2.07	2.38	2.70	3.30	3.11	3.56	2.07	5.38	2.48	5.66	1.07	38.38

Fig. 2 Averages of temperature and monthly precipitation for state climatic division, 1941-70

D

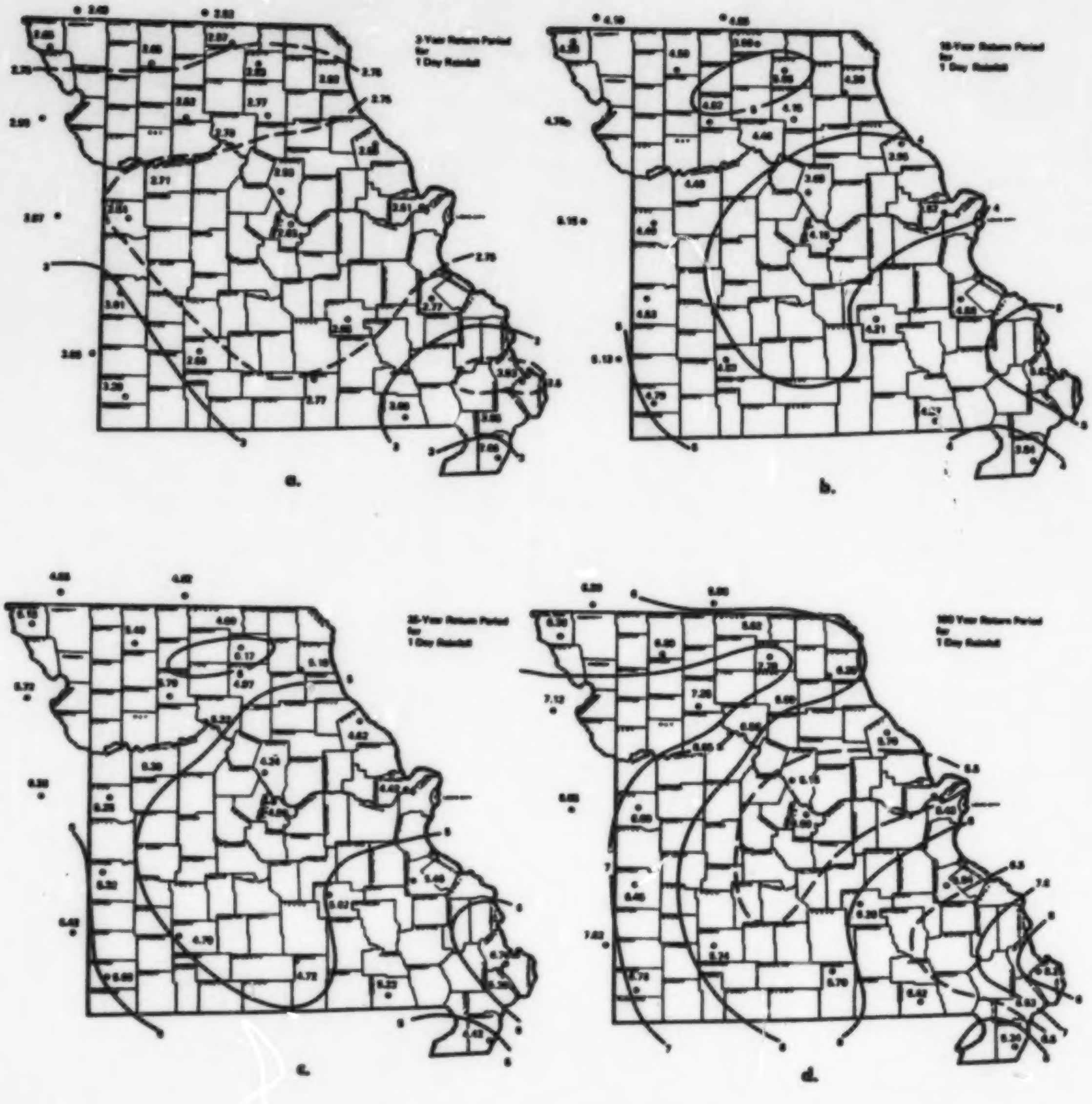
24160 WALLA WALLA WASHINGTON FAA 49-65
STATION STATION NAME YEARS

DAILY AMOUNTS

PERCENTAGE FREQUENCY OF
PRECIPITATION
(FROM DAILY OBSERVATIONS)

	AMOUNTS (INCHES)													PERCENT OF DAYS WITH MEASURABLE AMTS	TOTAL NO. OF OBS.	MONTHLY AMOUNTS (INCHES)		
PRECIP	NONE	TRACE	.01	.02-.05	.06-.10	.11-.25	.26-.50	.51-1.00	1.01-2.50	2.51-5.00	5.01-10.00	10.01-20.00	OVER 20.00					
SNOWFALL	NONE	TRACE	0.1-0.4	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.4	6.5-10.4	10.5-15.4	15.5-25.4	25.5-50.4	OVER 50.4					
SNOW DEPTH	NONE	TRACE	1	2	3	4-6	7-12	13-24	25-36	37-48	49-60	61-120	OVER 120			MEAN	GREATEST	LEAST
JAN	30.5	22.0	6.6	11.8	8.9	10.8	6.6	2.3	.4					47.4	527	2.20	5.25	.45
FEB	41.7	19.4	3.5	9.4	7.3	11.2	5.8	1.7						39.0	480	1.66	3.92	.41
MAR	50.1	13.7	2.8	9.7	5.5	10.6	6.6	.9						36.2	527	1.71	3.28	.42
APR	55.3	15.1	1.6	7.8	4.1	10.2	4.3	1.6						29.6	510	1.44	3.57	.15
MAY	60.0	14.2	3.0	4.7	3.2	7.4	4.4	2.5	.6					25.8	527	1.76	4.13	.40
JUN	67.6	12.0	1.6	6.5	3.3	4.3	2.5	1.6	.6					20.4	510	1.21	2.86	.27
JUL	86.1	6.6	1.1	1.9	1.3	1.3	1.1	.4						7.2	527	.35	2.12	.00
AUG	81.2	7.4	1.9	2.3	1.3	2.3	2.7	.6	.4					11.4	527	.71	2.70	.00
SEP	76.7	7.6	.6	4.9	2.4	4.5	1.6	1.6	.2					15.7	510	.89	2.85	.18
OCT	61.7	11.4	2.8	6.1	4.2	7.0	3.6	2.7	.6					26.9	527	1.79	4.42	.03
NOV	42.2	16.1	5.3	7.8	7.8	10.6	6.3	3.7	.2					41.8	510	2.28	4.14	.50
DEC	32.3	22.4	5.5	13.5	8.3	10.1	4.9	2.5	.6					45.4	527	2.14	4.69	.49
ANNUAL	57.2	14.0	3.0	7.2	4.8	7.5	4.2	1.8	.3					28.8	6209	18.15		

Fig. 1 Percentage frequency of daily amounts of precipitation


2-Year Return Period for 1 Day Rainfall
10-Year Return Period for 1 Day Rainfall
25-Year Return Period for 1 Day Rainfall
100 Year Return Period for 1 Day Rainfall
a.
b.
c.
d.

Maximum one-day rainfall amounts (inches) expected to occur with an average frequency of once in two years (a), once in 10 years (b), once in 25 years (c), and once in 100 years (d).

SOURCE: Rainfall frequency atlas for Missouri, Wisner, W.M., University of Missouri Extension Division, Columbia

Fig. 2 Maximum one-day rainfall amounts (2,10,25 and 100 year return periods) for Missouri

L

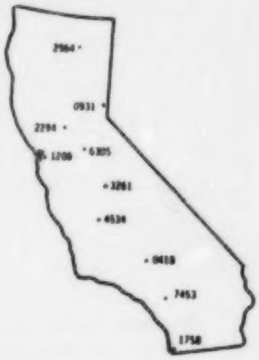
EXTREME MAXIMUM VALUES OF EVAPORATION AT SELECTED STATIONS

Evaporation extremes for consecutive day periods and frequencies of occurrence for stations in California adjusted to an irrigated environment and standard 4-ft USWB Class A pan

Station	Years of record	Adjust. factor	Occur. freq., years	1	2	3	4	5	7	9	11	15	20	25	30
				Consecutive days in period — Evaporation amounts, inches of water depth											
Backus Ranch (04-0418)	23	.775	2	0.70	1.30	1.86	2.40	2.91	3.90	4.87	5.78	7.60	9.85	12.14	14.37
			5	0.79	1.46	2.11	2.69	3.26	4.34	5.40	6.40	8.42	10.82	13.24	15.74
			10	0.85	1.55	2.26	2.87	3.47	4.63	5.74	6.80	8.97	11.44	13.95	16.62
			20	0.91	1.64	2.40	3.04	3.67	4.88	6.06	7.17	9.46	12.00	14.59	17.42
Boca (04-0931)	22	.775	2	0.37	0.67	0.95	1.23	1.51	2.06	2.61	3.15	4.19	5.51	6.77	8.03
			5	0.46	0.73	1.02	1.31	1.60	2.17	2.74	3.32	4.45	5.84	7.17	8.53
			10	0.51	0.78	1.06	1.36	1.66	2.24	2.84	3.43	4.61	6.05	7.42	8.88
			20	0.56	0.81	1.11	1.41	1.71	2.30	2.91	3.53	4.76	6.23	7.65	9.15
Burlingame (04-1206)	16	.900	2	0.36	0.66	0.94	1.20	1.46	1.97	2.48	2.98	3.98	5.23	6.45	7.65
			5	0.44	0.77	1.09	1.35	1.63	2.18	2.74	3.29	4.36	5.74	7.11	8.44
			10	0.49	0.85	1.19	1.44	1.74	2.30	2.91	3.49	4.60	6.08	7.52	8.96
			20	0.53	0.92	1.27	1.53	1.84	2.43	3.06	3.67	4.82	6.37	7.91	9.41
Chula Vista (04-1758)	30	1.00	2	0.33	0.61	0.89	1.16	1.42	1.94	2.45	2.95	3.94	5.18	6.41	7.63
			5	0.40	0.69	0.96	1.24	1.51	2.04	2.57	3.08	4.12	5.44	6.74	8.01
			10	0.45	0.74	1.01	1.29	1.57	2.11	2.64	3.17	4.24	5.61	6.96	8.26
			20	0.50	0.79	1.06	1.34	1.63	2.17	2.72	3.26	4.36	5.77	7.18	8.50
Davis 2 WSW (04-2294)	30	.800	2	0.44	0.81	1.14	1.45	1.76	2.34	2.93	3.52	4.66	6.10	7.52	8.95
			5	0.51	0.94	1.30	1.64	1.98	2.62	3.24	3.90	5.13	6.69	8.24	9.77
			10	0.56	1.02	1.40	1.77	3.12	2.79	3.45	4.14	5.45	7.07	8.71	10.29
			20	0.60	1.10	1.50	1.89	2.27	2.96	3.65	4.38	5.74	7.45	9.18	10.81
Fall River Mills Intake (04-2964)	27	.775	2	0.39	0.73	1.05	1.36	1.67	2.30	2.92	3.53	4.74	6.24	7.72	9.15
			5	0.46	0.83	1.17	1.51	1.85	2.54	3.23	3.89	5.19	6.84	8.46	10.04
			10	0.50	0.90	1.26	1.61	1.97	2.69	3.43	4.12	5.49	7.23	8.94	10.60
			20	0.54	0.96	1.33	1.70	2.07	2.83	3.60	4.32	5.76	7.59	9.39	11.13
Friant Govt. Camp (04-3261)	20	.800	2	0.54	1.03	1.50	1.96	2.42	3.30	4.18	5.03	6.74	8.79	10.88	12.94
			5	0.61	1.13	1.63	2.14	2.64	3.58	4.52	5.46	7.30	9.54	11.75	13.99
			10	0.65	1.18	1.72	2.25	2.78	3.77	4.74	5.74	7.66	10.00	12.33	14.67
			20	0.69	1.24	1.80	2.35	2.93	3.95	4.96	6.02	8.02	10.49	12.89	15.33
Kettleman City (04-4534)	16	.775	2	0.61	1.09	1.55	2.00	2.44	3.29	4.18	5.03	6.73	8.87	10.90	12.94
			5	0.75	1.27	1.77	2.28	2.77	3.70	4.70	5.66	7.54	9.90	12.08	14.32
			10	0.84	1.40	1.92	2.46	2.98	3.95	5.05	6.06	8.06	10.56	12.83	15.21
			20	0.93	1.50	2.06	2.63	3.18	4.19	5.35	6.43	8.53	11.16	13.52	16.01
Oakdale Woodward Dam (04-6305)	15	.800	2	0.60	1.04	1.46	1.86	2.25	3.03	3.80	4.58	6.05	7.86	9.69	11.45
			5	0.72	1.19	1.65	2.07	2.51	3.38	4.23	5.12	6.70	8.66	10.66	12.62
			10	0.80	1.29	1.77	2.22	2.68	3.59	4.50	5.46	7.12	9.16	11.29	13.36
			20	0.87	1.38	1.88	2.34	2.84	3.80	4.75	5.78	7.50	9.66	11.86	14.05
Riverside Exp. Station (04-7473)	30	.800	2	0.34	0.63	0.90	1.18	1.44	1.94	2.45	2.93	3.91	5.11	6.30	7.50
			5	0.38	0.70	1.01	1.30	1.59	2.14	2.70	3.24	4.34	5.66	6.98	8.29
			10	0.42	0.74	1.07	1.38	1.69	2.27	2.88	3.43	4.61	6.02	7.43	8.80
			20	0.44	0.78	1.14	1.46	1.78	2.40	3.04	3.63	4.88	6.37	7.87	9.30

CALIFORNIA STATION DESCRIPTIONS

Index number	Station name	Normal precip., inches	Elev., feet	North latitude °	'	West longitude °	'
04-0418	Backus Ranch	6.51	2645	34	57	118	11
-0931	Boca	20.80	5575	39	23	120	06
-1206	Burlingame	18.89	10	37	35	122	21
-1758	Chula Vista	9.98	9	32	36	117	06
-2294	Davis 2 WSW	16.46	60	38	32	121	46
-2964	Fall River Mills Intake	18.48	3340	41	01	121	28
-3261	Friant Government Camp	13.72	410	36	59	119	43
-4534	Kettleman City	6.42	250	36	00	119	58
-6305	Oakdale Woodward Dam	13.56	215	37	52	120	52
-7473	Riverside Exp. Station	11.45	986	33	58	117	21



Washington Agricultural Experiment Station
Bulletin 761

Fig. 1 Extreme maximum values of evaporation at selected stations

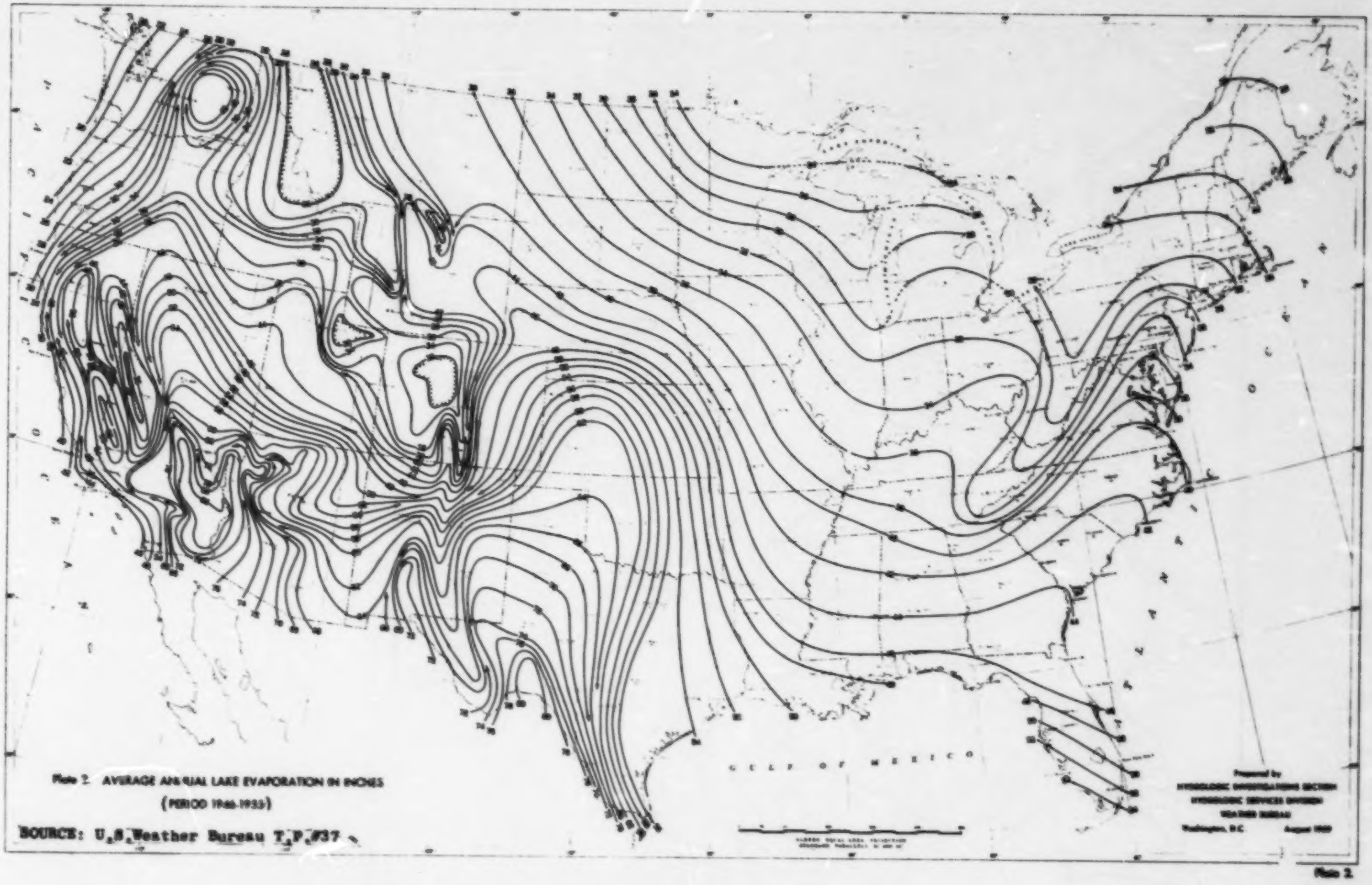


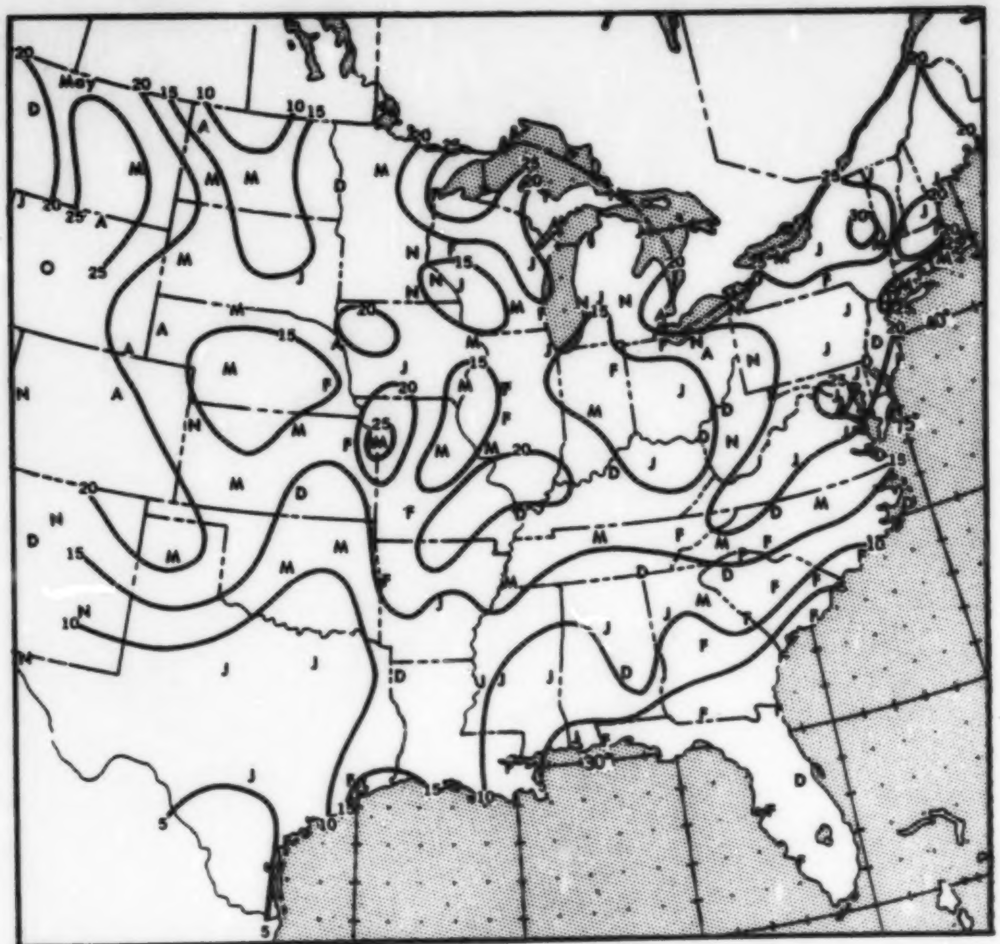
Plate 2 AVERAGE ANNUAL LAKE EVAPORATION IN INCHES
(PERIOD 1946-1955)
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
Prepared by
HYDROLOGIC INVESTIGATIONS SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
Washington, D.C.
Plate 2

SOURCE: U.S. Weather Bureau T.P. #37.

Fig. 2 Average annual lake evaporation, in inches

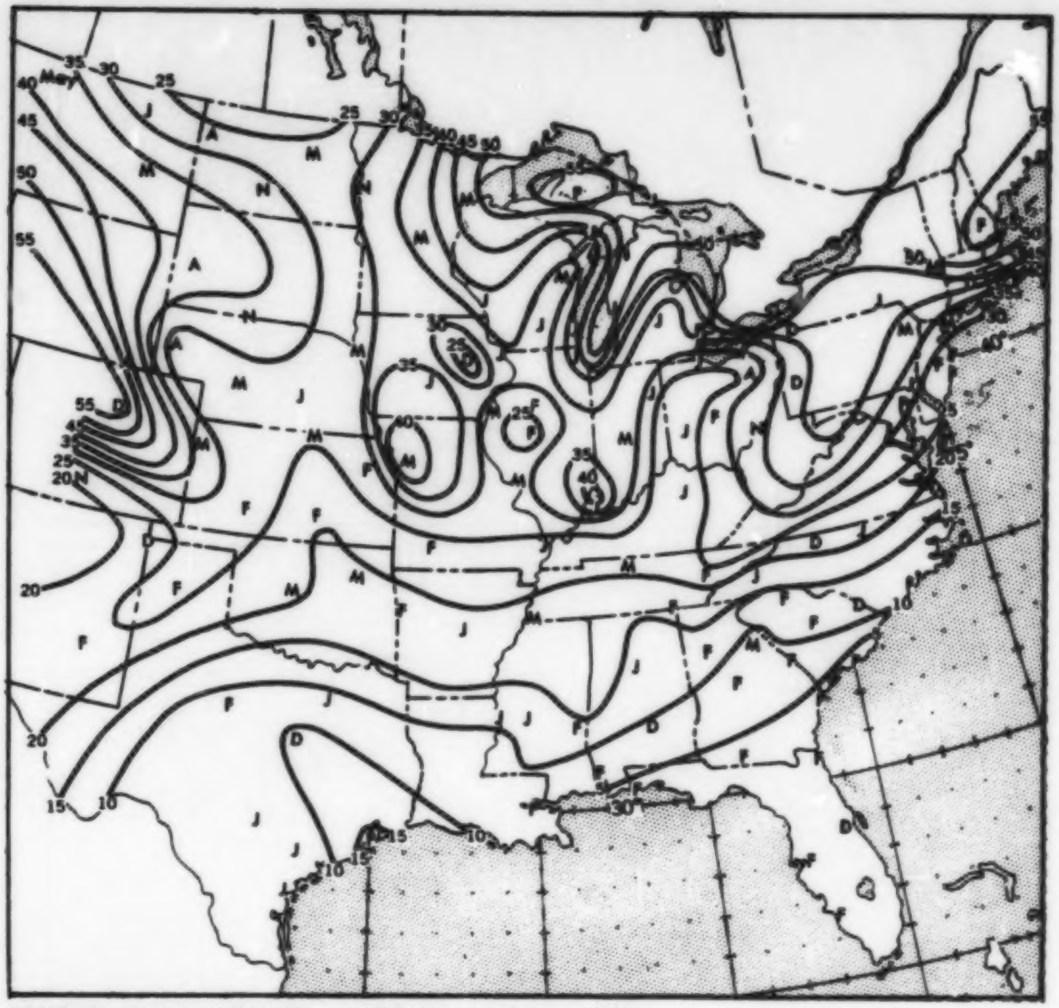
Reproduced from
best available copy.

F



SOURCE: Technical Note No. 10, U.S. Weather Bureau 1962

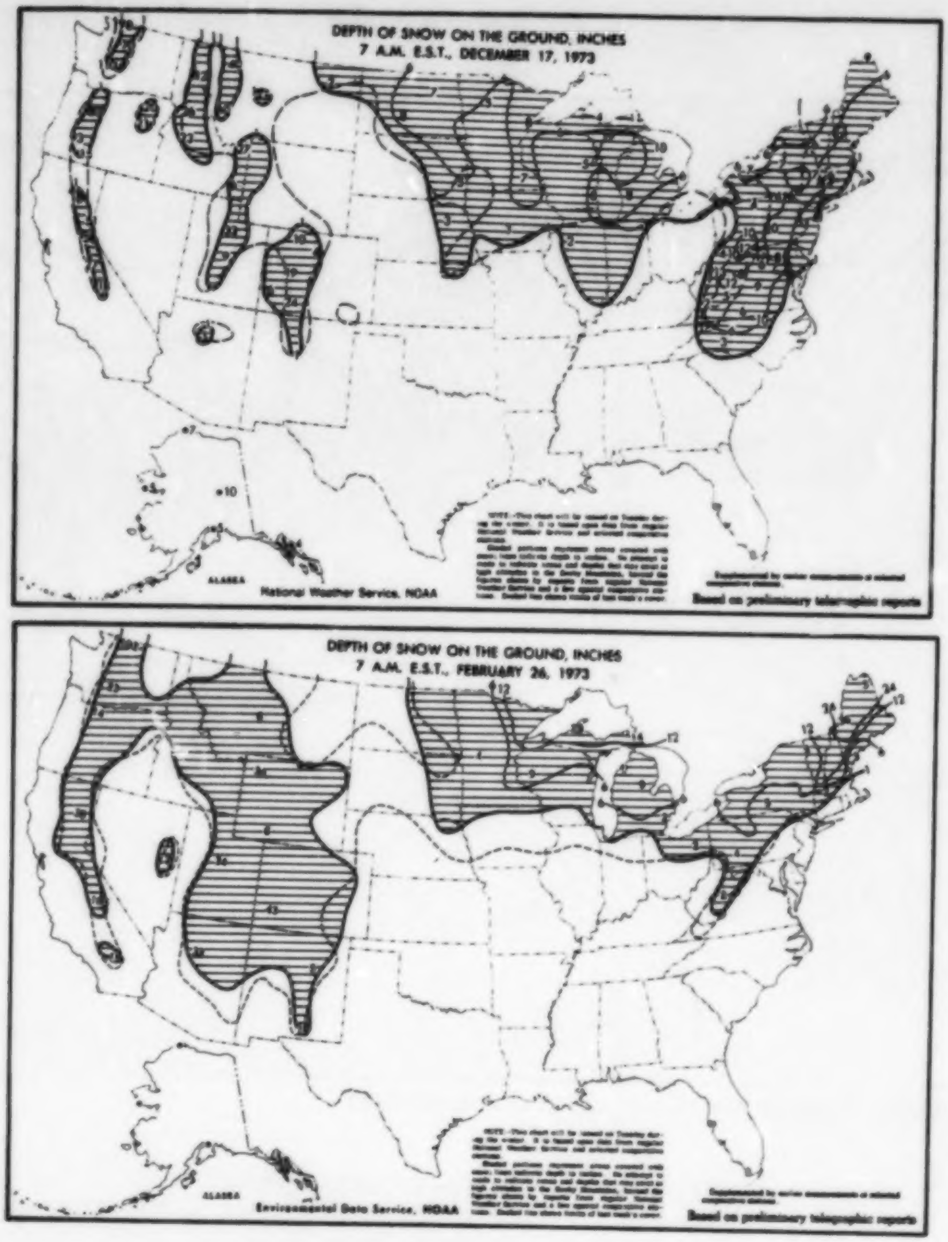
Fig. 1 Greatest 24 hour snowfall of record


35
30
40
May
25
45
50
55
J
A
M
N
25
30
35
40
45
30
F
D
55
45
35
25
20
20
15
10
15
10
15
10
30
20
15
10
40
35
25

SOURCE: Technical Note No. 10, U.S. Weather Bureau 1962

Fig. 2 Greatest monthly snowfall of record

G


DEPTH OF SNOW ON THE GROUND, INCHES
7 A.M. E.S.T., DECEMBER 17, 1973
ALASKA
National Weather Service, NOAA
Based on preliminary telegraphic reports
DEPTH OF SNOW ON THE GROUND, INCHES
7 A.M. E.S.T., FEBRUARY 26, 1973
ALASKA
Environmental Data Service, NOAA
Based on preliminary telegraphic reports

SOURCE: Weekly Weather and Crop Bulletin

Fig. 1 Depth of snow on ground (inches) on Feb. 26 and Dec. 17, 1973

WIND DIRECTION VERSUS WIND SPEED

Station: 12834 Daytona Beach, Florida   Hours: 24 observations per day   Period: 1956-1963

Station Name/Number, Type of Run - Monthly, Seasonal or Annual and Period of Record. Month or Season: Data for individual months, or seasons, combined for the period of record. Annual: Total of all months combined. Tabulations prepared for stations reporting less than twenty-four observations per day will carry a special notation indicating the actual hours of observations.

SPEED GROUPS: Knots (knots)
MPH (miles per hour)✓
MPS (meters per second)

A choice of units (as shown) is offered in the wind speeds. In general, no increase in cost will be incurred by altering class intervals, provided the number of classes shown is not exceeded.

MO: Month 01 = Jan., 02 = Feb., etc. where 12 = Dec.
AN = Annual
S1 = Season 1 (Dec., Jan., Feb.) S2 = Season 2 (Mar., Apr., May), etc.

Months selected for specific seasons may vary, but each season will be clearly defined in a separate document furnished with the tabulation.

CODE: No entry indicates that ALL weather conditions are included in the tabulation. When tabulations are prepared for selected weather conditions a series of special identification codes will be used and defined.

DIR: Wind Direction to 16 Compass Points and Calm.

The distribution represents mean conditions for the period specified. The direction is that from which the wind is blowing. Reporting practices vary somewhat among services and over different periods; however, it is common practice to prepare wind tabulations to 16 compass points and calm. The practice of reporting wind directions to 36 points began in January 1964. Tabulations can be prepared for stations and periods reporting to 36 points by using the conversion table shown below.

35,36,01 = N
02,03 = NNE
04,05 = NE
06,07 = ENE
08,09,10 = E
11,12 = ESE
13,14 = SE
15,16 = SSE
17,18,19 = S
20,21 = SSW
22,23 = SW
24,25 = WSW
26,27,28 = W
29,30 = WNW
31,32 = NW
33,34 = NNW

TOTAL: Total frequency by direction and by speed groups.

PERCENT: Total frequency by direction or speed group divided by the total number of observations for indicated period, rounded to tenths of percent. A percent shown as (.0) indicates an occurrence, but less than 0.05%.

AVG SPEED: Sum of speeds by direction divided by total number of observations in that direction category for tabulations prepared by computer. For those prepared by hand, an estimated value will be used based on the sums of the frequency times the cell mid-point for each class and divided by the total number of observations for that direction.

> The usual input for this tabulation is the simultaneous observation of wind speed and direction recorded hourly, twenty-four times a day. Most wind tabulations on file contain a minimum of five years of record with 24 observations per day. Lesser observations are used pending the availability of data.

Fig. 1 Description of a wind direction vs. wind speed distribution

WIND DIRECTION VERSUS WIND SPEED

N NAME/NUMBER 12834 Daytona Beach, Florida HOURS 24 Observations per day PERIOD OF RECORD 1956-1963

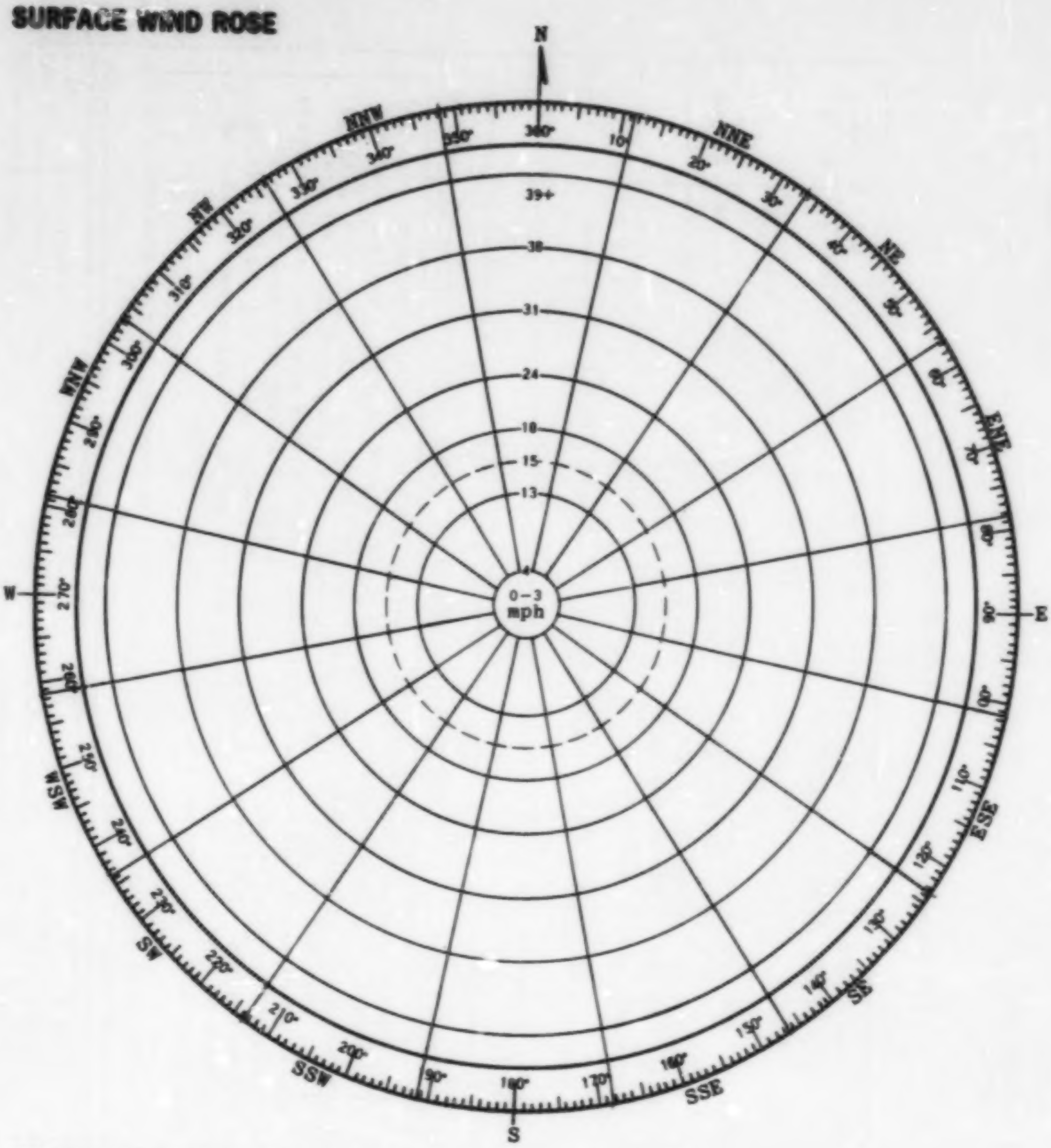
SPEED GROUPS IN M.P.H.

Mo	Code	Speed / Dir	0 — 3	4 — 7	8 — 12	13 — 18	19 — 24	25 — 31	32 — 38	39 — 46	47 & Gr.	Total	Percent	Avg Speed
01		N	28	84	151	165	53	19	2			502	8.4	12.6
		NNE	9	54	144	115	30	5				357	6.0	12.0
		NE	11	44	93	58	8					214	3.6	10.6
		ENE	11	29	78	41	8					167	2.8	10.5
		E	10	37	58	38	2					145	2.4	9.9
		ESE	7	30	56	51	8					154	2.6	11.3
		SE	16	53	51	41	13					174	2.9	10.2
		SSE	12	40	81	42	6					181	3.0	10.1
		S	23	61	84	50	14	5	1			238	4.0	10.4
		SSW	14	72	106	86	15					299	5.0	11.0
		SW	27	146	141	89	24	3				435	7.3	9.9
		WSW	23	131	173	89	27	1	1			455	7.6	10.3
		W	40	162	152	109	22	5	1	1		532	8.9	9.9
		WNW	28	145	205	120	16	3				517	8.7	9.9
		NW	43	265	248	126	17					721	12.1	9.0
		NNW	26	149	171	112	23	1				482	8.1	9.9
		Calm	378									378	6.4	
Total			706	1514	2055	1334	286	50	3	1		5951	100.0	9.7
Percent			11.9	25.4	34.5	22.4	4.8	.8	.1	.0			100.0	

USCOMM — NOAA — ASHEVILLE

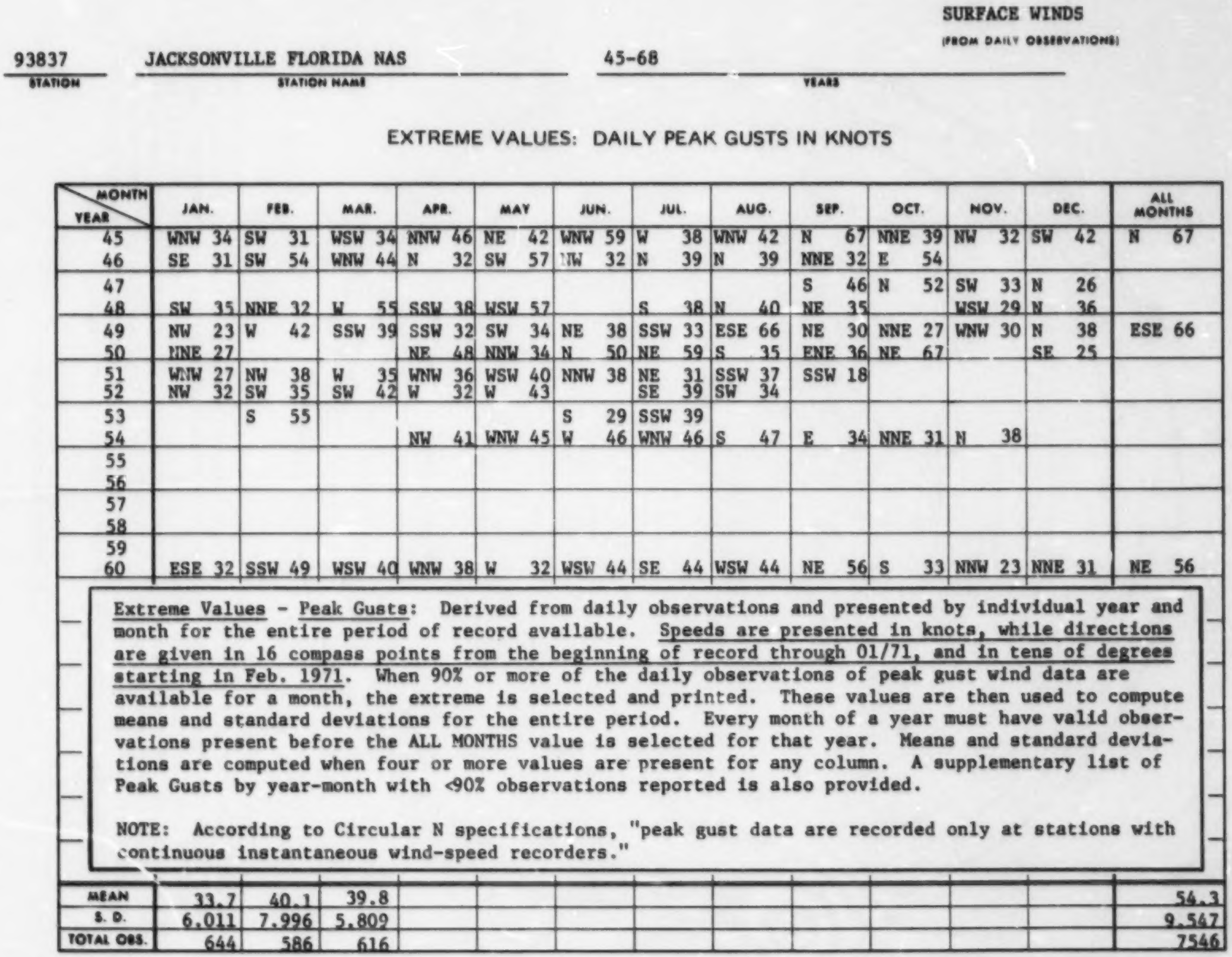
Fig. 2 January wind distribution at Daytona Beach, Florida (1955-63)

SURFACE WIND ROSE


N
NNW
NNE
NW
NE
WNW
ENE
W
E
WSW
ESE
SW
SE
SSW
SSE
S
360°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
90°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
39+
38
31
24
18
15
13
4
0-3
mph

THE WIND ROSE IS A SCALED GRAPHICAL PRESENTATION OF SURFACE WIND DATA IN TERMS OF SPEED AND DIRECTION. THE RADIAL LINES OF THE DIAGRAM ARE POSITIONED SO THAT AREAS BETWEEN THEM ARE CENTERED ON THE DIRECTION FROM WHICH THE WINDS ARE REPORTED. THE CONCENTRIC CIRCLES REPRESENT LIMITS BETWEEN SPEED GROUPS SECTORS, I.E., 4, 13, 15, 18, 24, 31, 38, AND 39+ MILES PER HOUR. RADII FOR THESE GROUPS ARE ACCURATELY SCALED TO THE RESPECTIVE SPEEDS. THE SEGMENTS ENCLOSED BY RADIAL LINES AND CONCENTRIC CIRCLES ON THE DIAGRAM REPRESENT WIND SPEED-DIRECTION COMBINATIONS. THE DATA FROM A WIND SUMMARY ARE TRANSFERRED TO THE APPROPRIATE AREA ON THE DIAGRAM AS A PERCENTAGE OF THE TOTAL OBSERVATIONS EXAMINED.

Fig. 3 Surface wind rose diagram



SURFACE WINDS
(FROM DAILY OBSERVATIONS)

93837
STATION

JACKSONVILLE FLORIDA NAS
STATION NAME

45-68
YEARS

EXTREME VALUES: DAILY PEAK GUSTS IN KNOTS

YEAR \ MONTH	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ALL MONTHS
45	WNW 34	SW 31	WSW 34	NNW 46	NE 42	WNW 59	W 38	WNW 42	N 67	NNE 39	NW 32	SW 42	N 67
46	SE 31	SW 54	WNW 44	N 32	SW 57	NW 32	N 39	N 39	NNE 32	E 54			
47									S 46	N 52	SW 33	N 26	
48	SW 35	NNE 32	W 55	SSW 38	WSW 57		S 38	N 40	NE 35		WSW 29	N 36	
49	NW 23	W 42	SSW 39	SSW 32	SW 34	NE 38	SSW 33	ESE 66	NE 30	NNE 27	WNW 30	N 38	ESE 66
50	NNE 27			NE 48	NNW 34	N 50	NE 59	S 35	ENE 36	NE 67		SE 25	
51	WNW 27	NW 38	W 35	WNW 36	WSW 40	NNW 38	NE 31	SSW 37	SSW 18				
52	NW 32	SW 35	SW 42	W 32	W 43		SE 39	SW 34					
53		S 55				S 29	SSW 39						
54				NW 41	WNW 45	W 46	WNW 46	S 47	E 34	NNE 31	N 38		
55													
56													
57													
58													
59													
60	ESE 32	SSW 49	WSW 40	WNW 38	W 32	WSW 44	SE 44	WSW 44	NE 56	S 33	NNW 23	NNE 31	NE 56
MEAN	33.7	40.1	39.8										54.3
S. D.	6.011	7.996	5.809										9.547
TOTAL OBS.	644	586	616										7546

Extreme Values - Peak Gusts: Derived from daily observations and presented by individual year and month for the entire period of record available. Speeds are presented in knots, while directions are given in 16 compass points from the beginning of record through 01/71, and in tens of degrees starting in Feb. 1971. When 90% or more of the daily observations of peak gust wind data are available for a month, the extreme is selected and printed. These values are then used to compute means and standard deviations for the entire period. Every month of a year must have valid observations present before the ALL MONTHS value is selected for that year. Means and standard deviations are computed when four or more values are present for any column. A supplementary list of Peak Gusts by year-month with <90% observations reported is also provided.

NOTE: According to Circular N specifications, "peak gust data are recorded only at stations with continuous instantaneous wind-speed recorders."

Fig. 4 Daily peak wind gusts (surface), by month and year

PERCENTILES OF MONTHLY MAXIMUM AND MINIMUM TEMPERATURES

WACO, TEXAS - CONNALLY AFB

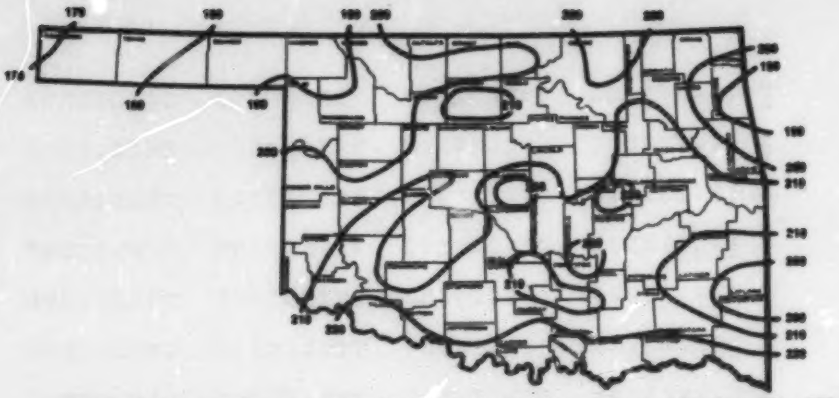
PERCENTILE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAXIMUM												
100	84	90	93	98	99	102	109	107	105	96	89	85
99	80	86	88	91	95	100	104	106	103	95	86	80
97	78	80	85	89	93	99	102	104	99	92	84	78
95	77	78	84	88	93	98	101	103	97	91	83	76
90	73	75	81	85	91	96	100	102	96	90	80	73
85	71	74	79	84	90	96	99	101	95	89	78	71
80	69	72	78	83	89	95	99	100	95	87	76	69
75	67	70	76	83	89	94	98	99	94	86	75	68
50	58	62	69	78	85	92	96	96	90	80	68	60
MINIMUM												
0	9	7	22	33	43	54	66	59	49	35	20	13
1	11	21	25	36	46	58	67	62	54	37	26	16
3	15	23	29	39	51	62	68	66	55	42	28	21
5	18	25	30	41	52	63	69	67	57	44	31	24
10	23	28	33	44	56	65	71	69	60	46	34	27
15	26	31	35	46	58	67	72	70	62	48	35	30
20	29	32	38	48	60	68	72	71	64	50	38	31
25	30	34	39	49	61	68	73	72	65	51	39	33
50	36	40	46	57	65	71	75	73	70	58	46	39
3 HR MIN												
0	10	9	22	35	45	57	67	61	51	35	22	19
1	12	21	27	38	49	60	68	65	55	40	27	20
3	16	24	30	41	52	63	69	67	57	44	29	22
5	19	26	31	42	54	64	71	69	59	46	32	25
10	24	30	34	46	57	67	72	71	61	48	35	29
15	28	32	37	48	59	68	73	72	63	50	37	31
20	30	34	39	49	61	69	73	72	65	51	39	33
25	32	35	41	51	62	70	74	73	66	53	40	35
50	38	42	48	58	66	73	76	76	71	60	47	40
6 HR MIN												
0	13	10	23	36	47	58	69	63	54	36	26	17
1	14	21	28	40	52	62	70	67	57	42	29	21
3	18	26	31	43	54	64	72	70	59	46	31	24
5	20	28	33	45	56	66	72	71	61	48	34	27
10	25	31	36	48	59	69	74	72	64	50	37	30
15	30	34	39	50	62	70	74	73	66	52	39	33
20	31	35	41	52	63	71	75	74	67	53	41	35
25	33	37	43	53	64	72	76	75	68	55	43	36
50	40	44	50	60	68	75	78	78	73	62	50	42

WICHITA FALLS, TEXAS

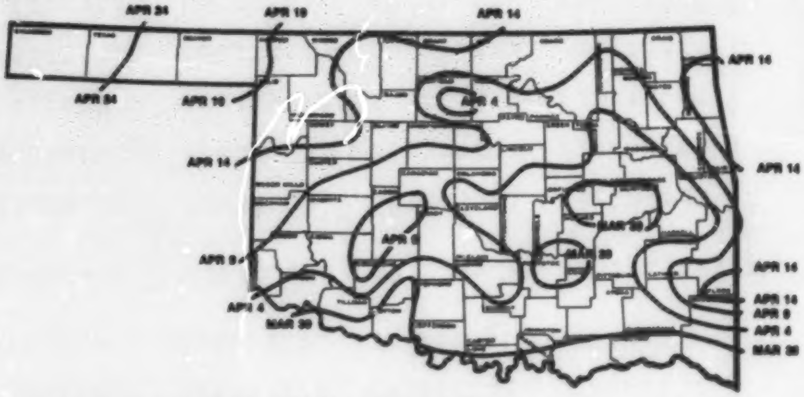
PERCENTILE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAXIMUM												
100	85	87	92	98	101	108	109	111	106	100	87	87
99	78	85	90	95	99	104	107	107	104	96	83	81
97	75	82	87	92	97	102	105	106	101	94	82	75
95	74	80	85	91	95	101	104	104	100	93	81	72
90	71	73	81	88	93	99	102	103	98	90	78	69
85	68	72	79	86	91	98	101	102	96	88	75	66
80	65	70	76	84	90	97	100	101	95	86	73	64
75	63	68	74	82	89	96	99	100	94	85	72	62
50	54	58	66	75	84	92	96	97	89	78	63	55
MINIMUM												
0	-1	1	14	29	37	51	58	56	47	26	15	8
1	6	12	20	31	42	55	62	59	48	36	21	11
3	9	19	23	33	46	57	65	62	51	38	23	15
5	12	20	25	36	48	59	67	64	53	40	25	18
10	16	23	28	39	52	62	69	66	56	44	28	22
15	20	25	31	42	54	64	70	68	58	45	31	24
20	22	27	32	43	56	65	70	69	59	46	32	26
25	24	29	34	45	57	66	71	70	61	48	33	27
50	30	35	40	51	62	70	74	73	66	55	40	32
3 HR MIN												
0	3	3	15	30	39	53	59	58	48	29	18	9
1	7	14	20	33	44	56	64	60	50	36	22	12
3	10	19	24	35	47	59	67	64	53	40	25	16
5	13	21	26	38	50	60	68	66	54	42	26	19
10	18	24	29	41	53	63	70	68	57	45	30	23
15	22	26	32	44	56	65	71	69	59	46	32	25
20	23	28	34	45	57	66	72	71	61	48	34	27
25	25	30	35	47	59	67	73	72	62	50	35	29
50	32	36	42	53	64	72	76	75	68	56	42	34
6 HR MIN												
0	6	4	16	33	41	54	62	61	50	31	20	11
1	8	15	22	35	45	58	65	62	52	39	23	14
3	12	20	26	37	49	61	69	66	55	42	26	18
5	15	22	28	40	52	62	70	68	57	44	28	21
10	19	26	32	43	55	65	71	70	60	48	31	25
15	23	28	34	46	58	67	72	71	62	49	34	27
20	25	30	36	47	59	68	74	73	64	51	36	29
25	27	32	38	49	60	69	75	74	65	52	37	31
50	34	39	44	56	66	75	78	77	70	59	44	36

SOURCE: U.S. Army, Aberdeen Proving Grounds, MD. (J.P.Doner 1972)

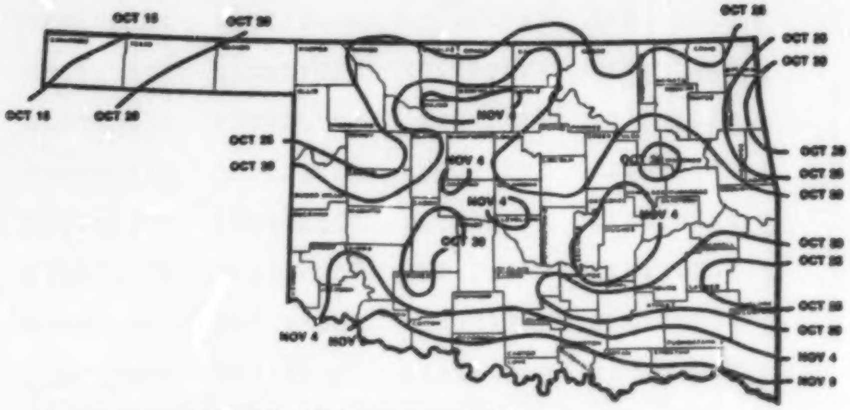
Fig. 1 Percentiles of monthly maximum and minimum temperatures (° F)


170
180
190
200
200
200
170
180
190
200
190
200
210
210
200
210
200
210
220

Mean length of freeze-free period (days) between last 32° (F.) temperature in Spring and first 32° (F.) temperature in Fall.


APR 24
APR 19
APR 14
APR 14
APR 24
APR 19
APR 4
APR 14
APR 14
MAR 29
APR 9
APR 9
MAR 30
APR 14
APR 4
APR 14
MAR 30
APR 14
APR 9
APR 4
MAR 30

Mean occurrence date of last 32° (F.) temperature in Spring.


OCT 15
OCT 20
OCT 25
OCT 20
OCT 30
OCT 15
OCT 20
NOV
OCT 25
OCT 30
NOV 4
OCT 30
NOV 4
NOV 4
OCT 30
OCT 25
OCT 25
OCT 30
OCT 30
OCT 25
OCT 25
OCT 30
NOV 4
NOV
NOV 4
NOV 9

Mean occurrence date of first 32° (F.) temperature in Fall.

SOURCE:Freezing Temperatures in Oklahoma, OSU Ext. Center

Fig. 2 Freeze data for Oklahoma

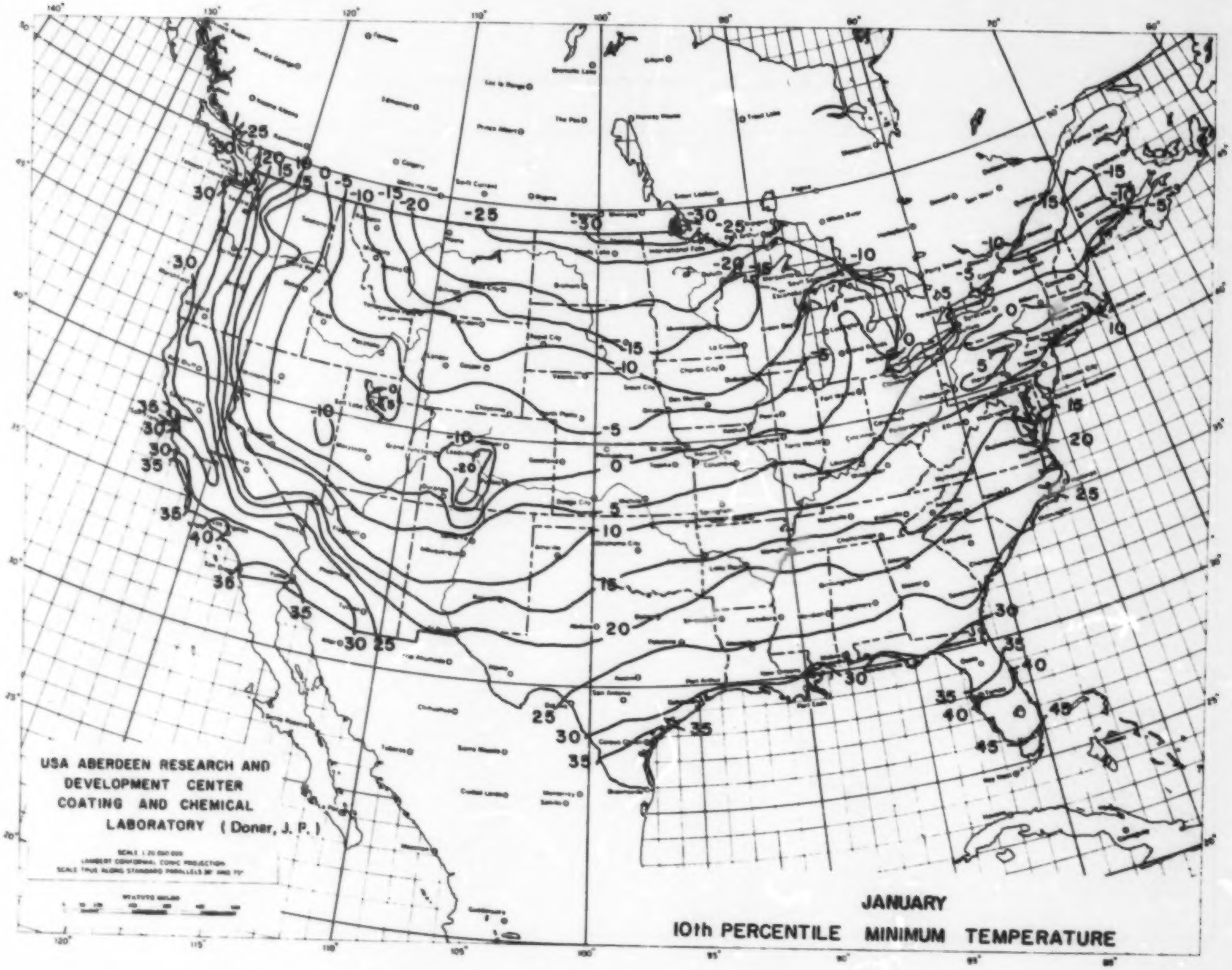

USA ABERDEEN RESEARCH AND
DEVELOPMENT CENTER
COATING AND CHEMICAL
LABORATORY (Doner, J. P.)
LAMBERT CONFORMAL CONIC PROJECTION
STATUTE MILES
JANUARY
10th PERCENTILE MINIMUM TEMPERATURE

Fig. 3 Tenth percentile of minimum temperature for January

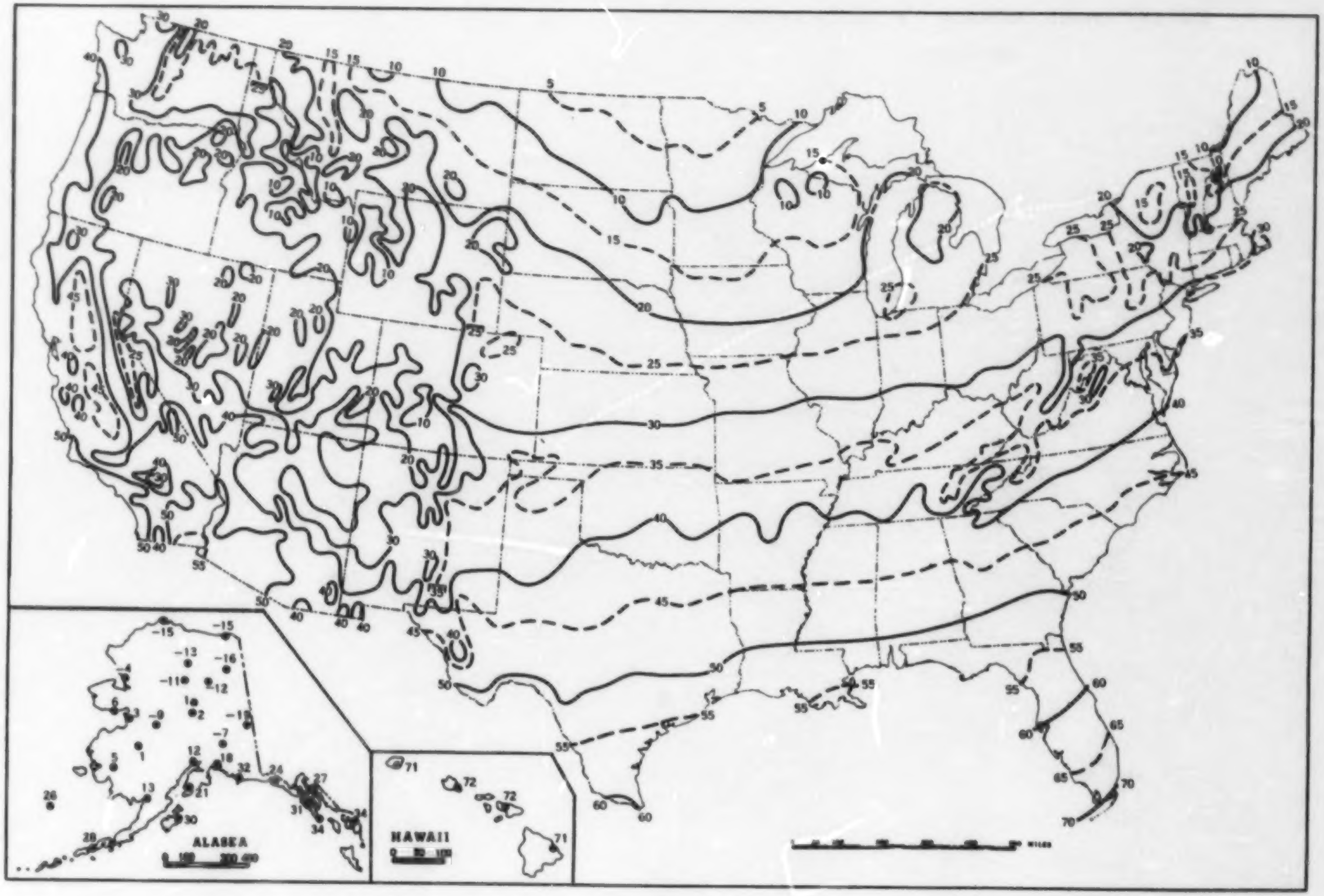
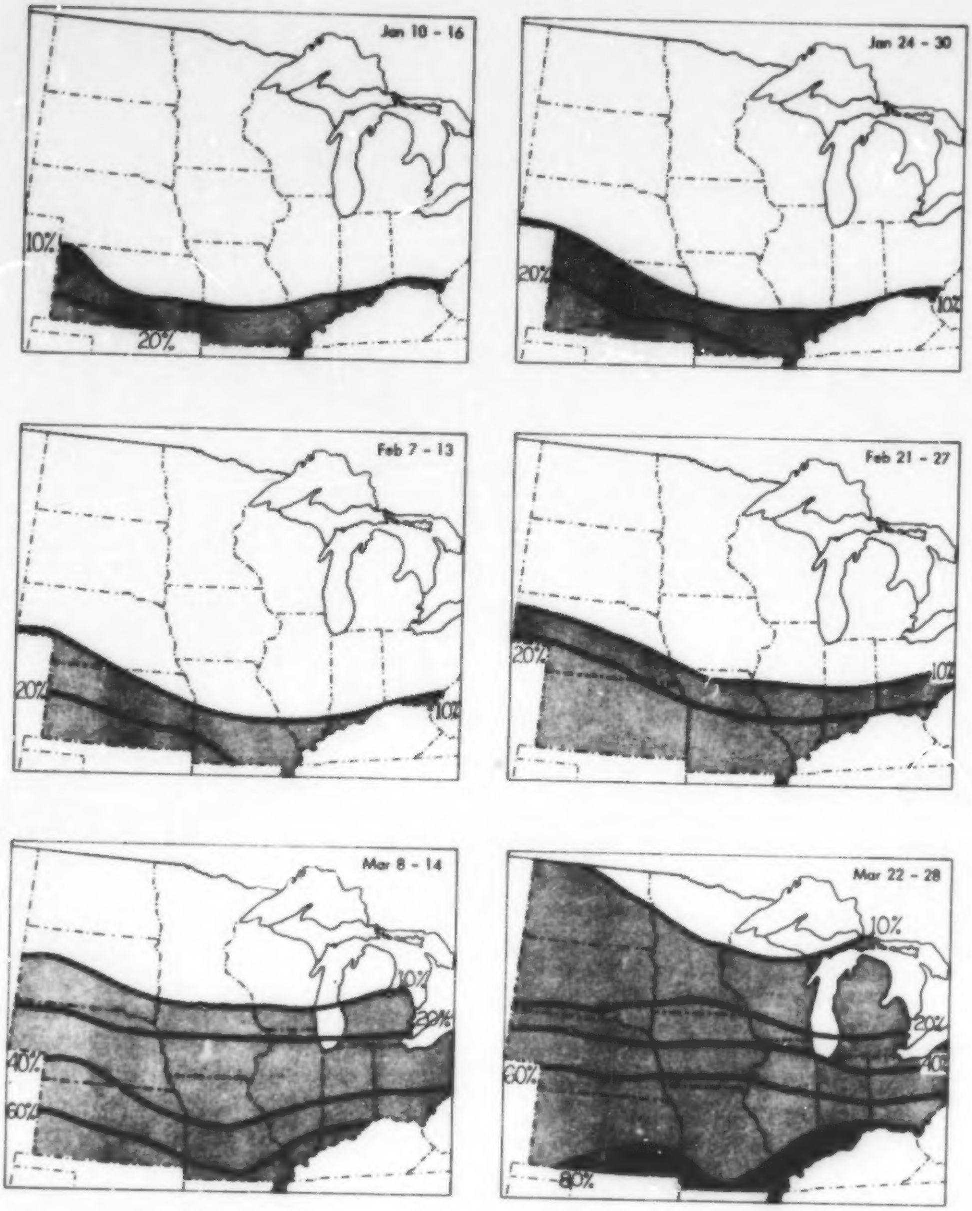

ALASKA
0 100 200 400
HAWAII
0 50 100
MILES
5
10
15
20
25
30
35
40
45
50
55
60
65
70

Fig.4 Normal daily average temperature (°F), 1941-70 - January

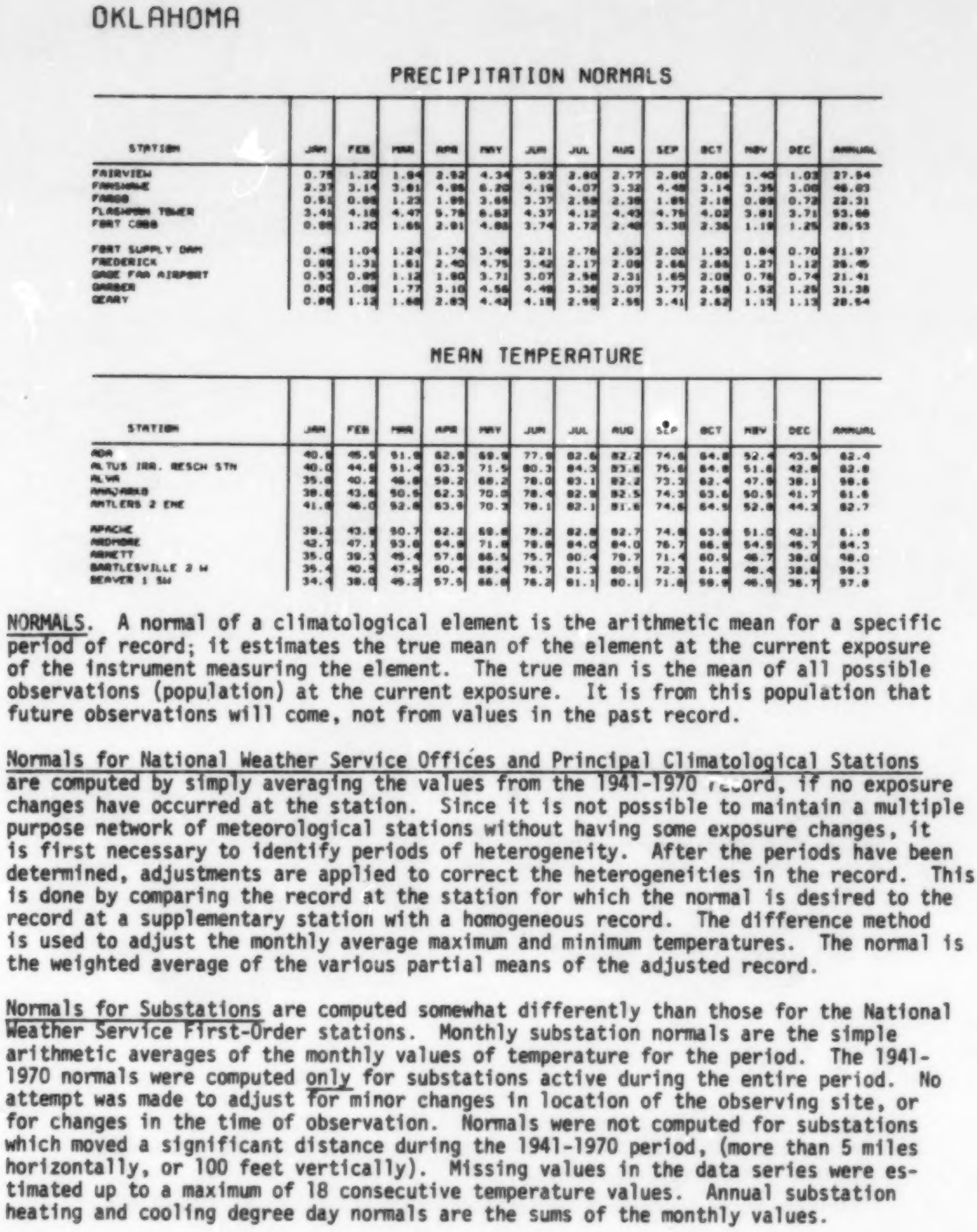

Jan 10 - 16
10%
20%
Jan 24 - 30
20%
10%
Feb 7 - 13
20%
10%
Feb 21 - 27
20%
10%
Mar 8 - 14
10%
20%
40%
60%
Mar 22 - 28
10%
20%
40%
60%
80%

RUNS OF 15 OR MORE DAYS WITH MAXIMUM ABOVE 40F. EACH MAP PRESENTS THE PERCENTAGE OF YEARS HAVING SUCH PERIODS BEGIN DURING THE WEEK INDICATED.

Reprinted from " Periods with Temperatures Critical to Agriculture," Decker, W.L.

Fig. 5 Runs of 15 or more days with maximum temperature above 40 °F, by week

J



OKLAHOMA

PRECIPITATION NORMALS

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FAIRVIEW	0.79	1.20	1.84	2.92	4.34	3.83	2.80	2.77	2.80	2.06	1.40	1.03	27.84
FANSHAWE	2.37	3.14	3.81	4.86	6.20	4.16	4.07	3.32	4.48	3.14	3.35	3.00	46.03
FARGO	0.51	0.86	1.23	1.85	3.65	3.37	2.58	2.38	1.85	2.18	0.88	0.72	22.31
FLASHMAN TOWER	3.41	4.16	4.47	5.76	6.62	4.37	4.12	4.43	4.79	4.02	3.81	3.71	53.66
FORT COBB	0.86	1.20	1.65	2.01	4.88	3.74	2.72	2.48	3.38	2.36	1.19	1.25	28.53
FORT SUPPLY DAM	0.48	1.04	1.24	1.74	3.48	3.21	2.76	2.53	2.00	1.83	0.84	0.70	21.87
FREDERICK	0.88	1.31	1.81	2.40	4.75	3.42	2.17	2.08	2.66	2.66	1.27	1.12	26.45
GAGE FAA AIRPORT	0.53	0.85	1.12	1.80	3.71	3.07	2.56	2.31	1.65	2.08	0.76	0.74	21.41
GARBER	0.80	1.08	1.77	3.10	4.56	4.48	3.36	3.07	3.77	2.58	1.52	1.25	31.38
GEARY	0.88	1.12	1.68	2.83	4.42	4.18	2.98	2.55	3.41	2.62	1.13	1.13	28.54

MEAN TEMPERATURE

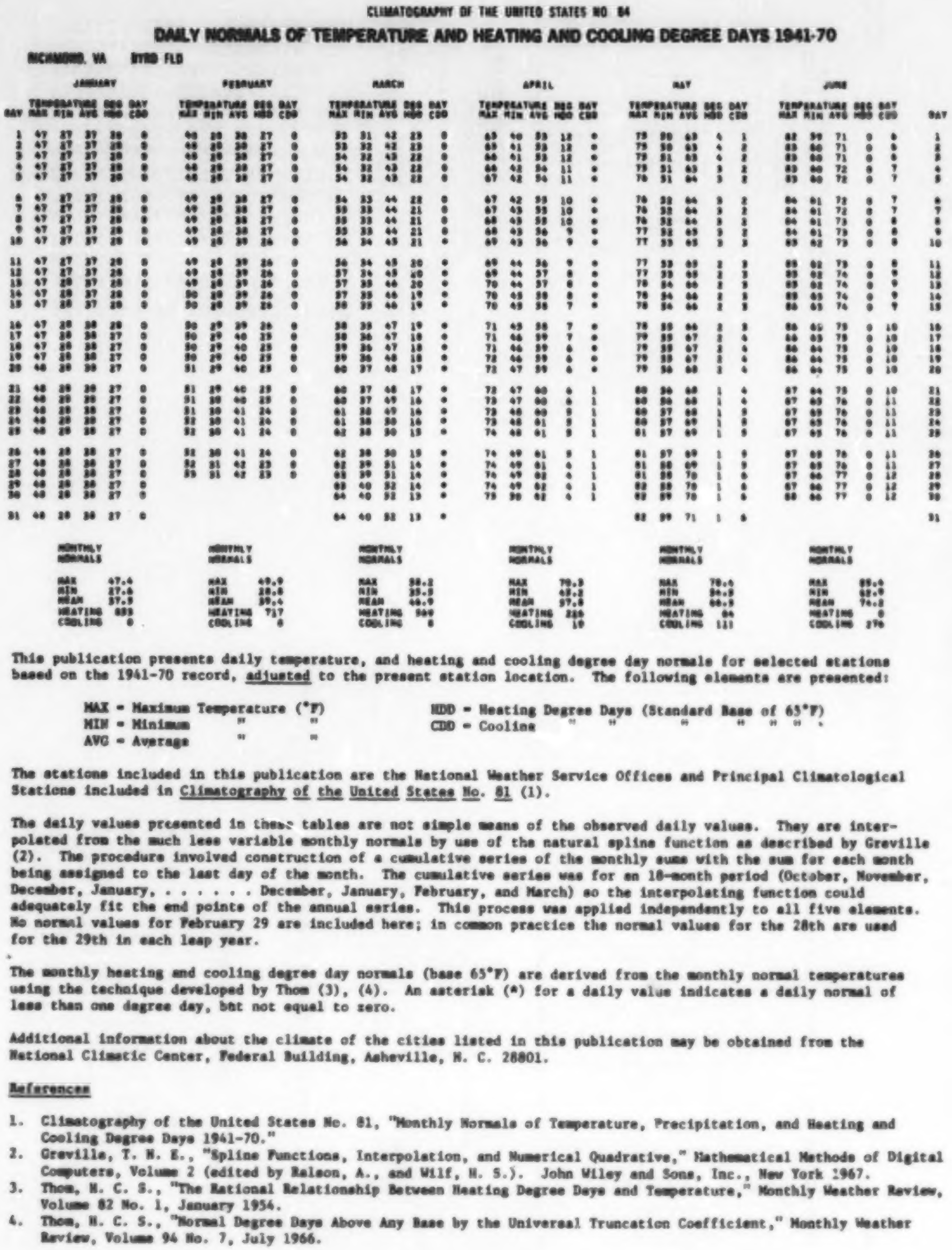
STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ADA	40.9	45.9	51.9	62.9	69.9	77.9	82.6	82.2	74.6	64.8	52.4	43.5	62.4
ALTUS IRR. RESCH STN	40.0	44.8	51.4	63.3	71.5	80.3	84.3	83.6	75.6	64.8	51.6	42.8	62.8
ALVA	35.6	40.2	46.8	58.2	68.2	78.0	83.1	82.2	73.3	62.4	47.9	38.1	58.6
ANADARKO	38.6	43.6	50.5	62.3	70.0	78.4	82.9	82.5	74.3	63.6	50.5	41.7	61.6
ANTLERS 2 ENE	41.6	46.0	52.6	63.9	70.3	78.1	82.1	81.6	74.6	64.5	52.6	44.3	62.7
APACHE	38.2	43.9	50.7	62.2	69.6	78.2	82.8	82.7	74.8	63.8	51.0	42.1	6..8
ARDMORE	42.7	47.1	53.6	64.6	71.6	78.6	84.0	84.0	76.7	66.8	54.9	45.7	64.3
ARNETT	35.0	39.3	45.4	57.8	66.5	75.7	80.4	79.7	71.4	60.5	46.7	38.0	58.0
BARTLESVILLE 2 W	35.4	40.5	47.9	60.4	68.4	76.7	81.3	80.9	72.3	61.8	48.4	38.6	58.3
BEAVER 1 SW	34.4	38.0	45.2	57.5	66.6	76.2	81.1	80.1	71.6	59.9	45.9	36.7	57.8

NORMALS. A normal of a climatological element is the arithmetic mean for a specific period of record; it estimates the true mean of the element at the current exposure of the instrument measuring the element. The true mean is the mean of all possible observations (population) at the current exposure. It is from this population that future observations will come, not from values in the past record.

Normals for National Weather Service Offices and Principal Climatological Stations are computed by simply averaging the values from the 1941-1970 record, if no exposure changes have occurred at the station. Since it is not possible to maintain a multiple purpose network of meteorological stations without having some exposure changes, it is first necessary to identify periods of heterogeneity. After the periods have been determined, adjustments are applied to correct the heterogeneities in the record. This is done by comparing the record at the station for which the normal is desired to the record at a supplementary station with a homogeneous record. The difference method is used to adjust the monthly average maximum and minimum temperatures. The normal is the weighted average of the various partial means of the adjusted record.

Normals for Substations are computed somewhat differently than those for the National Weather Service First-Order stations. Monthly substation normals are the simple arithmetic averages of the monthly values of temperature for the period. The 1941-1970 normals were computed only for substations active during the entire period. No attempt was made to adjust for minor changes in location of the observing site, or for changes in the time of observation. Normals were not computed for substations which moved a significant distance during the 1941-1970 period, (more than 5 miles horizontally, or 100 feet vertically). Missing values in the data series were estimated up to a maximum of 18 consecutive temperature values. Annual substation heating and cooling degree day normals are the sums of the monthly values.

Fig. 1 Monthly normals (1941 - 70) are published by state



CLIMATOGRAPHY OF THE UNITED STATES NO 84

DAILY NORMALS OF TEMPERATURE AND HEATING AND COOLING DEGREE DAYS 1941-70

RICHMOND, VA BYRD FLD

This publication presents daily temperature, and heating and cooling degree day normals for selected stations based on the 1941-70 record, adjusted to the present station location. The following elements are presented:

MAX - Maximum Temperature (°F)
MIN - Minimum " "
AVG - Average " "
HDD - Heating Degree Days (Standard Base of 65°F)
CDD - Cooling " " " " " " .

The stations included in this publication are the National Weather Service Offices and Principal Climatological Stations included in Climatography of the United States No. 81 (1).

The daily values presented in these tables are not simple means of the observed daily values. They are interpolated from the much less variable monthly normals by use of the natural spline function as described by Greville (2). The procedure involved construction of a cumulative series of the monthly sums with the sum for each month being assigned to the last day of the month. The cumulative series was for an 18-month period (October, November, December, January, ... December, January, February, and March) so the interpolating function could adequately fit the end points of the annual series. This process was applied independently to all five elements. No normal values for February 29 are included here; in common practice the normal values for the 28th are used for the 29th in each leap year.

The monthly heating and cooling degree day normals (base 65°F) are derived from the monthly normal temperatures using the technique developed by Thom (3), (4). An asterisk (*) for a daily value indicates a daily normal of less than one degree day, but not equal to zero.

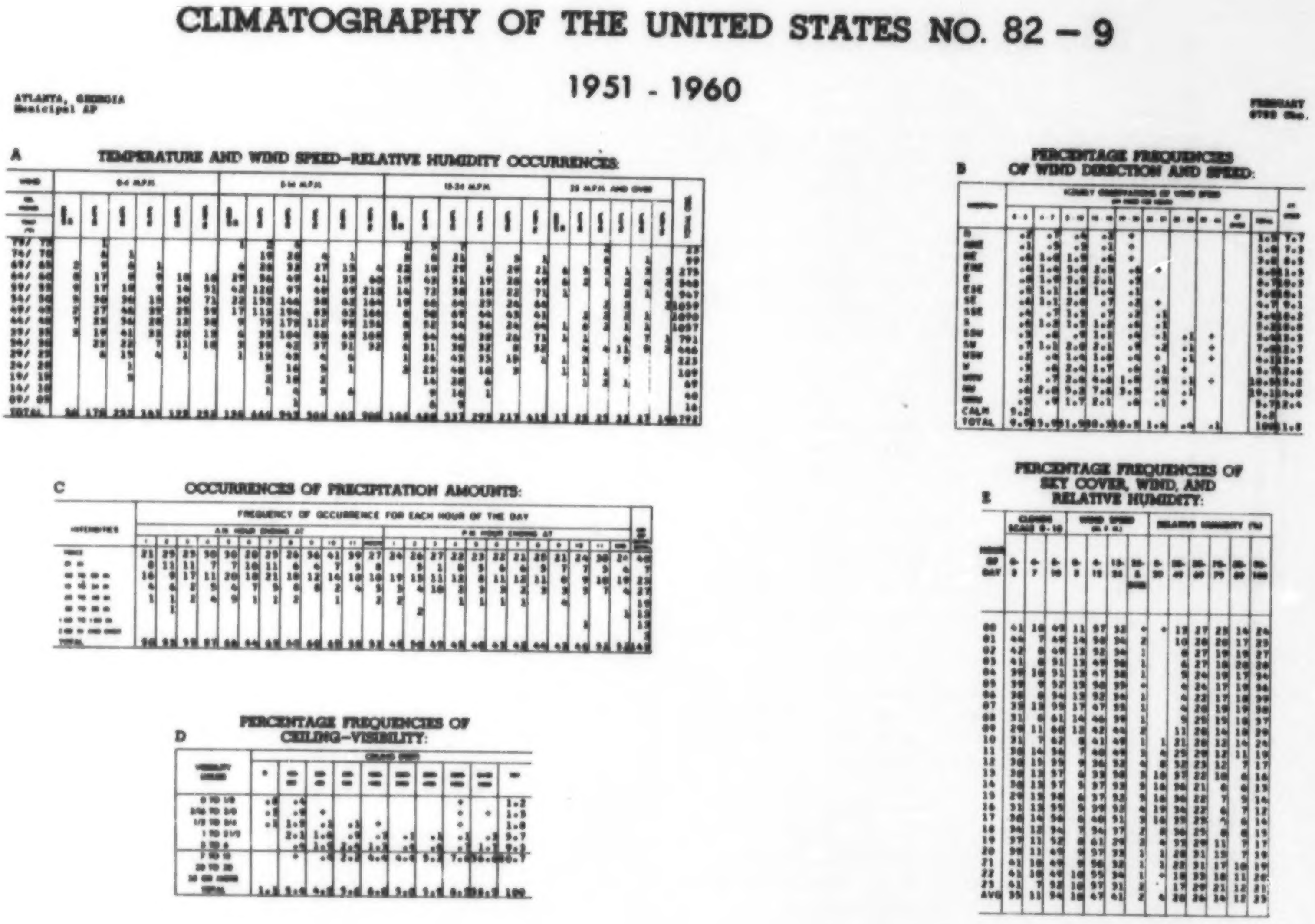
Additional information about the climate of the cities listed in this publication may be obtained from the National Climatic Center, Federal Building, Asheville, N. C. 28801.

References

1. Climatography of the United States No. 81, "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1941-70."
2. Greville, T. N. E., "Spline Functions, Interpolation, and Numerical Quadrative," Mathematical Methods of Digital Computers, Volume 2 (edited by Ralson, A., and Wilf, H. S.). John Wiley and Sons, Inc., New York 1967.
3. Thom, H. C. S., "The Rational Relationship Between Heating Degree Days and Temperature," Monthly Weather Review, Volume 82 No. 1, January 1954.
4. Thom, H. C. S., "Normal Degree Days Above Any Base by the Universal Truncation Coefficient," Monthly Weather Review, Volume 94 No. 7, July 1966.

Fig. 2 Climatography of the United States # 84 daily normals of heating and cooling degree days 1941 - 70

K



CLIMATOGRAPHY OF THE UNITED STATES NO. 82 – 9

1951 - 1960

ATLANTA, GEORGIA
Municipal AP

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

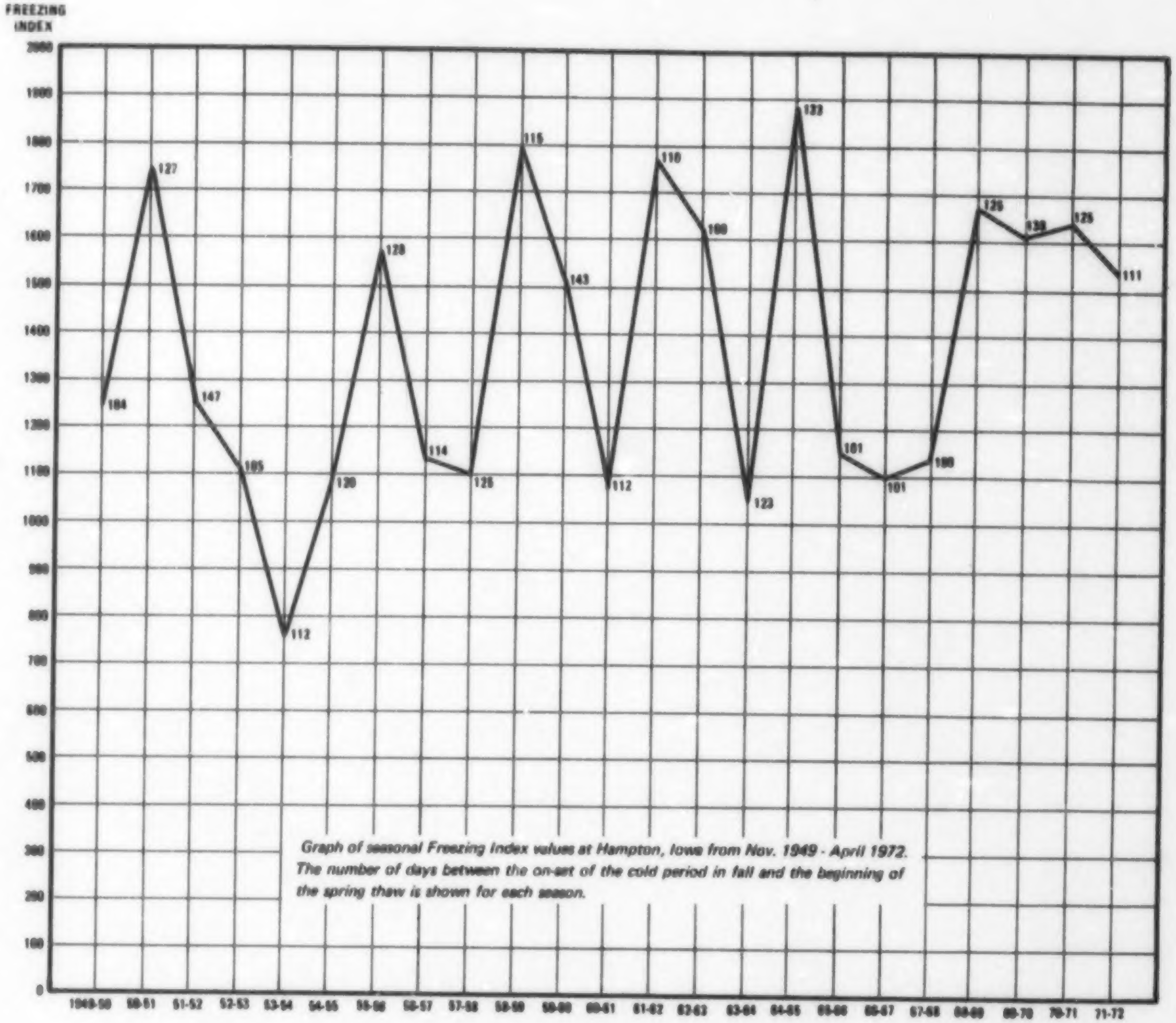
B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

C OCCURRENCES OF PRECIPITATION AMOUNTS:

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

Fig. 1 Climatography of the United States # 82 – a summary of ten years (1951 - 60) of hourly observations



Graph of seasonal Freezing Index values at Hampton, Iowa from Nov. 1949 - April 1972. The number of days between the on-set of the cold period in fall and the beginning of the spring thaw is shown for each season.

Fig. 2 Freeze indices and duration of cold periods at Hampton, Iowa for selected seasons